Physics Tomorrow: New Cosmology and Gravitation in Modern Physics

Kirill Vankov

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Abstract

In this work, we present a new Cosmology of the Grand Universe, which is a relativistic model of the steady-state, matter-antimatter symmetric Universe in infinite space-time. The Grand Universe consists of matter and antimatter bounded Universes, which are floating in an infinite space filled with the physical Grand Universe Background. The Grand Universe methodology is based on Fundamental Principles of Classical Mechanics and Special Relativity Dynamics, and it explains all basic cosmological observations consistently with Fundamental Principles of Physics. Issues of relationships of cosmological models with Relativistic Gravitation theories and Modern Physics branches are discussed. A detailed critical analysis of the Standard Cosmological Model is conducted, especially, in part of its methodological basis, the metric of space expansion as the solution of GR field equations. The attention is paid to the damaging role of abstract mathematical constructions in Physical theories. The issues related to philosophical criteria of true versus false in Cosmology and Modern Physics, in general, are discussed as well. The conclusion is made that the Standard Cosmological Model suffers numerous inner contradictions due unproven assumptions and the corresponding conflicts with observations, so it must be abandoned in favor of the Grand Universe Model.

**Physics Tomorrow* is a series of our future papers devoted to Modern Physics problems. This paper is a revision of the first one in the series. Here, a text improvement and corrections of some accidental errors are made.

†Contact at `https://www.vankov.org`. The site is primarily reflects a natural human property of curiosity about physical world, especially, our on edge knowledge of it, and a conception of truth in Mathematical and Physical Sciences. In other words, we are interested in current status and all aspects of Modern Physics Frontiers. The site is intended to give a room for an exchange of opinions of critically minded scientists free of mainstream dogmas and safe from mass media noise. E-mail: *kirill @ vankov.org*.

Contents

"The growth of knowledge depends entirely upon disagreement."
— Karl Popper, *The Myth of the Framework*

1 Introduction

A challenging purpose of Cosmology at all times is to explain observations of Cosmos and Physical Nature. A review of cosmological models shows a notable trend of encountering the strangeness with a deeper penetration into the cosmic space. A history of Cosmology is rich in unexpected discoveries of puzzling Astrophysical and Cosmological phenomena, which, having no satisfactory explanation, remained mysteries. In this way, Physical Science, in general, has been developing since old ages with *New Physics* often caming to the scene, for good or for bad. Not only Physics Community but common people are eager to know "true stories" from "true science" in a layman's language, but how to distinguish between "truth" from "untruth", or "belief in truth"?

The problem is that, what is seen in far skies, is not always evident. With models becoming more sophisticated and hypothetical, a growing departure of cosmological models from physical reality toward hypothetical New Physics finds its way. To compete with rival models, cosmologists often introduce additional ad hoc assumptions enlarging a parametric freedom of the model. This allows it to acquire a status of *a true theory by the criterion of fitting.* Another way of "fitting" is to redefine model ingredients for a larger flexibility of observation treatments.

The issue of *true* versus *false* in Natural Sciences was always considered subject to the epistemological judgment. Besides the fitting criterion, there is a philosophical and logical criterion, which requires a theoretical simplicity and minimal, if any, radical departures from fundamental physical principles cumulated the whole knowledge from past (Occam's razor philosophy). In this sense, none of the existing cosmological models can be considered satisfactory. Unfortunately, the old philosophical question about a recognition of a truly new scientifically valued knowledge is hardly seem of academic importance for Modern Physics and Philosophy.

In this work, our new Grand Universe Model is compared with *the Standard Cosmological Model* (SCM). The latter is still the leading model, though, in growing doubts. It is more complex and hypothetical than other physically reasonable rival models. By power of a mainstream collective belief, the Model is taken for granted as the most feasible scientific conception of the Universe. It would be out of the scope of this work to discuss other cosmological models along with hundreds of remarkable Astronomical, Astrophysical, and Cosmological observations. The related numerous literature is easily available, e.g. [1, 2, 3, 4].

The proponents of the SCM may insist that observations give us a solid scientific evidence of the existence of New Physics phenomena, which, though, looking strange, are well fit to the Model, till a truly better alternative explaining New Physics comes to the scene. To disprove the SCM, one needs to get through a scrutiny of hundreds of parts of it. We argue, however, that no matter how many observations have been accounted for, it is still a tiny 4-spacetime slice of image of the Universe in its enormity. More doubts come with observations of progressive precision. They often bring new controversies rather than clarification.

The densities of matter and energy, which is the key parameters in the Standard Model, seems to be instructive in retrospect to observations of new strange phenomena, such as *Dark Matter*, *Dark Energy*, *Neutrino mass*, and others. Facing a failure of physical understanding, cosmologists labeled them with common language names, actually making the Big Bang in all its modifications the New Physics umbrella.

Here and after, we use the term *New Physics* in relationship to, firstly, observations, which permanently remained unexplained puzzles, labeled by some ordinary name, for example, "Dark Matter" or "Dark Energy", and in this way are used in model parametrization; secondly, related to theoretical concepts, conflicting with Science of Physics, for example "Early Universe after its singular origination". Such concepts are often associated with a pure mathematical structure. This is *bad New Physics*, or pseudo-Physics. There is a real *good New Physics*, which arises from a discovery of a new phenomenon, physical explanation of which is expected in a logically meaningful generalization of old theories being approximations of new ones, with radically new ideas to be implemented.

Concerns with conundrums and New Physics in the Standard Model piled up by the end of 20th Century, as shown in "Principles of Physical Cosmology" by the outstanding developer of Modern Physical Cosmology, Princeton Professor P.J.E. Peebles [1], as well as in publications of other authors. The nowadays growing concerns are signs of the oncoming crisis.

We criticize the current leading model, the Standard Cosmological Model, for highly hypothetical assumptions, in fact, involving bad New Physics. The major assumptions are referred to the General Relativity (GR) gravitational field theory without a thorough analysis of their relevance and applicability to the Cosmological Model framework. In this work, our critical analysis is presented in details restricted by the paper volume, and a new cosmological model is formulated.

Our approach to developing a new cosmological model is guided by Fundamental Physical Principles and Special Relativity methodology, and driven by common sense and human creativity, – in a spirit of Karl Popper's Philosophy of Science. We support the current movement "to defend the integrity of Physics" [5] (in the noted article, clarity of the message to Physical community is impressive; the issue of "Crisis at the Edge of Physics" has reached out to public, see [6]).

We claim that the proposed Alternative Model explains all basic cosmological observations treated in terms of Fundamental Physics with new insights into Physical Nature problems, and with no appeal to any kind of bad New Physics.

The following abbreviations are used:
- *Black Hole* (BH)
- *Cosmic Microwave Background* (CMB)
- *Cosmic Rays* (CRs)
- *Einstein's Field Equations* (EFE)
- *Friedmann-Lemaître-Robertson-Walker metric* (FLRW metric)
- *General Relativity* (GR)
- *Our Observed Universe* (OU)
- *Special Relativity* (SR)
- *Standard Cosmological Model* (SCM)
- *The Grand Universe* (GU)
- *The Grand Universe Physical Background* (GUB)
- *Typical Evolving Universes* (TU)
- Λ *Cold Dark Matter model* (ΛCDM model)

2 The Grand Universe Cosmological Model

2.1 Basic Physical concepts of New Cosmological Model

The GU conceptual idea was presented years ago, [7, 8, 9, 10], at the time when we have insufficient understanding of exact solutions of Einstein's field equations and their significance in the cosmological models. It was clear that a promotion of alternatives to the Big Bang Cosmology would be hard without a thorough analysis of the Physical Foundations of the GR

Theory and its role in Cosmology. The studies have taken a lengthy time, and now, upon its completion, the proposal is put forward.

Among the main known Modern Physics problems, there are two puzzles, Matter-Antimatter Asymmetry and Ultra-High Energy Cosmic Rays, – which are largely neglected in cosmological models. We consider these "puzzles" the primary unresolved problem in Physical Cosmology. This consideration led us to the original idea of steady-state, matter-antimatter symmetric Grand Universe, which consists of bounded Typical Universes equally made of either matter or antimatter. They are floating in the infinite space-time filled with the physical Grand Universe Background. The latter is the space for bodies attracting by Newtonian gravitational force, subject to Special Relativity Dynamics, we use. Also, this is a physical vacuum, a field of a quantum carrier of the force, the long standing problem of relativistic gravitational field theory.

The GUB is a high-energy relativistic medium of gamma rays, particles, as well as matter and antimatter fragments. This is the place for an eternal evolution of Typical Universes interacting with each other and with the GUB itself. Notice, a physical process of matter annihilation and pair creation consists of single nuclear reactions between nuclear particles rather than bulk materials.

The GU is a world of gravitation, which always existed and will exist with no spatial boundaries, – there is no question about its origin. The scientific questions to be asked are about an evolution of its parts and a state on the whole. The GU is in the equilibrium state due to a balance of continuous matter-antimatter annihilation and creation and a statistical mechanism of matter-antimatter separation on the largest cosmic scale. Quite naturally, our Observed Universe is an ordinary cosmological phenomenon resulting from a collision of a pair of Universes made of matter and antimatter, when some parts, survived or damaged, fly away, and some could be left at the center mass ares. The collision is not an annihilation catastrophe but rather a lengthy continuous explosion. It has various possible scenarios complicated by statistical randomness, in particular, leading to a recession of survived galaxies, as in the OU case.

An annihilation of matter is accompanied by a continuous release of kinetics energy of flying away galaxies, which loose their binding energies. In addition, a radiation pressure creates radial pushing forces and torques. As a results, galaxies fly away. Our place in the Observable Cosmology belongs to the initially large enough but limited volume containing the center of mass of colliding TUs.

Galaxies in freely floating TUs must be very different from those observed, say, in the Milky Way: they are expected to be much more bounded to the central super-massive core (say, "a Black Hole"), more densely packed and rotate about the Black Hole, the closer to the core, the higher their masses and speed. Hence, they would fly away in an orderly manner.

The receding galaxies are observable in the red-shifted light from our initial position occurred to be significantly void of matter in a large space volume. The redshift is explained in terms of SR Dynamics, namely, the motional Doppler effect, the gravitational time dilation, and some other factors, all in a relationship with the distance and time scales to be assessed from assumptions made in the reconstruction of annihilation collision involving two colliding TUs of different masses. Those special issues are discussed later in more details.

The detected Cosmic Microwave Background is a usual electromagnetic radiation, which is locally in thermal (black body) equilibrium with the surrounding matter including fragments and dust. The CMB temperature has been decreasing during the adiabatic process of matter expansion.

The GU conception gives a room to consistent explanations of basic cosmological observations, also provides with new insights within Fundamentals of Classical and Modern Physics and beyond.

We start with the issues of Matter/Antimatter and Cosmic Rays in Open Universe, which are not addressed in the Standard Cosmological Model and remained unresolved.

2.2 The issue of matter-antimatter symmetry in the GU Model

In literature, the problem is usually formulated in terms of Baryon Asymmetry while we are talking about the matter in it most generality. It includes positive protons (baryons) and negative electrons (leptons) with a change of sign of the charge and the magnetic moment in anti-matter. Consequently, the neutron has its counterpart, the anti-neutron, and so forth.

Our Observed Universe is apparently a matter dominated Universe. But could this fact justify the SCM, in which one of the Fundamental Physical Principles, – the Matter/Antimatter Symmetry, is broken for no particular reason? In our view, there is now sufficient evidence justifying the Principle breaking.

The idea to resolve the problem is to admit an existence of multiple Universes of symmetrically matter and anti-matter compositions having finite masses and sizes. We call them the Typical Universes evolving in an infinite space, which just exist in the Grand Universe being the Steady State Universe on the largest cosmic scales.

One needs to think about physical conditions, in which such a picture is possible. First of all, there is a mechanism of statistical separation of matter and antimatter in the process of annihilation and creation, [10]. Yet, the TUs evolutions should be viewed in the process of their interaction with each other and with the Grand Universe Physical Background. The GUB must be a relativistic physical medium containing massive and massless matter, the product of TUs distraction in matter-antimatter collisions. At the same time, the GBU has to provide material for the TU evolving.

Our Observed Universe is an exemplary case of TU interaction in the form of collision of two matter/antimatter TUs of significantly different sizes; one of them or both have to be perished. Overall conditions of TUs interactions with each other and with the GUB must be just right for the GU to be self-sustained in its continuous self-destruction and recreation of the eternal steady state.

The question arises: is there the antimatter in Our Observable Universe?

We believe that antimatter is actually around in a considerable amount. It is, indeed, hardly distinguishable from ordinary matter but its indirect consequences can be falsely recognized as unusual phenomena. In the GU model, the annihilation process is not abrupt and still observable. Here is not a full list of unusual phenomena in the SCM explained by observable matter/antimatter annihilation in different forms:

- Quasars: annihilation of large clouds about attractors with luminosity change;
- Star “explosions” and gamma bursts with release of huge amount of high energy;
- Universe large scale structure: walls and filaments separated by immense voids;
- Events of unusual radiation flares around the Milky Way bulge;
- X-ray busts of a huge intensity and strangeness of central Black Holes in galaxies;
- “Unusual” Dynamics of galaxies.

2.3 The Primary Cosmic Rays and the Causality Principle

There are numerous galactic and intergalactic contributions to the observed Cosmic Rays. The problem is that they contain particles of ultra-high energies $E > 10^{18}$ eV reaching values 10^{21} eV and beyond, physical origin of which is a mystery [11, 12]. For decades, physicists tried to unveil a mysterious mechanism of particle acceleration up to such an inexplicably ultra-high energy, though, physical mechanism of such accelerations are beyond a technical imagination. We state that it cannot be explained by any physically reasonable mechanism of their origination within the Observed Universe, and suggest radically new idea consistent the GU Model.

The explanation of this phenomenon with no need of "acceleration" is, as follows. The Primary CRs come from the GUB radiation in the form of extremely high energy particles. During penetration through the Universe, they loose energy. The observed ultra-high energy tail is a contribution from the GUB radiation. The latter is transformed by the process of inelastic scattering leading to deceleration of primary GUB particles. Thus, the observed ultra-high energy particles come from the ultra-high relativistic tail of the GU Background (as a result of the deceleration within the Observable Universe rather than the acceleration).

We predict that the observed CR ultra-high energy tail contains antimatter particles, since the Primary CRs must be matter-antimatter symmetric, and it must contain equal amount of protons and anti-protons as well as electrons and positrons. Also, it must contain the corresponding gamma rays of ultra-high energy.

We think that the GU Steady State must exists under and due to the conditions of weakening casual connections between GU hierarchy members so that a total casual disconnection eventually occurs. This is a breakage of the Causality Principle on the largest GU scale, which leads to new physical phenomena. Consider a particle departed from some, say, TU-1, which can travel most of the time in the GU background at a distance exceeding a scale of casual connection that is, the time exceeding a TU lifespan. The particle could reach some another TU-2 having a relative speed with respect to the TU-1, at random value, however high. A relative velocity dispersion has to grow with a travel distance. This is the idea of a statistical formation of the Lorentz invariant energy spectrum of Primary CRs containing ultra-high energy particles.

The CR problem is closely related to the role of matter/antimatter symmetry in connection with GU physical features, as next:

- Long distance space transparency;
- Locally verifiable Causality Principle and its breakage in the GU scale;
- Origination of the primary Cosmic Rays characterized by locally observable Lorentz invariant energy spectrum;
- Hierarchal matter structures and variation of the physical units;

It should be emphasized that the GU methodology of treatment of observations in terms of SR Dynamics and its Newtonian limit is radically different from the GR methodology in the SCM. The corresponding issues, in some details, are analyzed in the following sections.

3 Critical Analysis of the SCM and its GR methodological basis

3.1 The necessity to analyze the GR role in the SCM

While proposing the Alternative Cosmology, we take a responsibility to analyze the SCM to reveal its methodological deficiencies in explanations and treatments of cosmological observations and predictions of new physical phenomena. As noted in [1], its explanations and predictions are model dependent. The current version is the ΛCDM, which preserves the Big Bang idea of "Beginning" followed by the FLRW metric space expansion.

We have two-fold basic objection to the Model. First of all, it concerns the Beginning with its early stage of the Inflation. The instant appearance is an extrapolation to "the initial time" $t = 0$ from the observable recession of galaxies. "The Beginning" is a step-by-step description of instant appearance of physical world from nothing. It tells a Bible-like fiction about passing through Plank and the Inflation epochs of about 10^{-33} second of duration after the Big Bang explosion at zero time (though the meaning of time unit of "second" is not clear). Then, the light comes accompanied by appearance of different kind of non-charged then also charged particles, star and galaxy seeds... We have no more comments, since it cannot be scientifically criticized. Many scientists refuse to accept it and, for this sole reason, reject the whole Model. However, the rejection without a solid acceptable Alternative is not the solution expected by Physical Community.

Secondly, we criticize the post-Inflation scenario and its methodological basis borrowed from the solutions of Einstein's field equation and their GR interpretation. Our doubts and disagreements will be discussed in parts of physical and mathematical aspects of the SCM in comparison with Alternative methodology.

As seen from the Introduction, there is also an important philosophical part of the problem such as the criteria of true versus false. Other related issues concern perceptions of Abstract Mathematics concepts in Philosophy of Modern Physics. Typically disputed topics concern philosophical aspects of the Cosmological Principle, its meaning in the context of different Causality conditions and interfacing with other concepts such as "the observability of events", "the horizon", "the observer", "the observable universe", "the observable part of the universe", "the prediction", and others, e.g. [13, 14, 15, 16, 17].

Controversies in the GR research is not a surprise in view of the fact that the meaning of Einstein's field equations was historically altered and were continually argued. As discussed in [18], there is no physically meaningful definition of the gravitational field in the GR theory.

3.2 Review of the physical aspects of the Standard Cosmological Model

Expansion, and the Hubble's Law.

In the SCM, the Observed Universe is viewed in accordance with the Cosmological Principle postulated for the post-Inflationary era. It states that the Observable Universe is seen homogeneous and isotropic on the scale of galactic super-clusters. This means that any observer sees the same "smooth" picture of the observable part of the Universe regardless of observer's location.

In mathematical terms, the Universe Expansion is a metric expansion of the space with a scaling factor $a(t)$ in the flat metric. Currently, it is the Friedmann-Lemaître-Robertson-Walker (FLRW) metric, which is known as an exact solutions of Einstein's field equations. As noted, the above metric is embedded in the nowadays ΛCDM Model. Actually, the different authors derived and treated it differently, so the metric reflects their common idea of the expanding Universe as opposed to Einstein's original concept of the stationary Universe.

In physical terms, the metric is characterized by the critical mass/energy density, Ω, which currently includes ordinary and dark matter, massive neutrinos, dark energy, and radiation, contributions of which change over time. In this form, the metric is put in the relationship with the observed redshift. The metric of space-time expansion defines the time/distance scales in the Hubble's Law.

The Model requires a carefully tuned balance of Dark Matter and Dark Energy with only about 4 percent of the ordinary matter in the Observed Universe. The Dark Energy due to the tiny cosmological constant Λ is dominant. It is not clear how this fact is related to to the GR physical vacuum concept [19].

The recession of galaxies due to the metric expansion actually means that a locally moving galaxies must be eventually trapped by metric and dragged farther away with the expanding space. In our view, in Physics, a particle can be dragged by a field of forces but not by a metric unless the metric is formulated mathematically and used for description of a mathematical world apart from the Fundamental Physical Principles. The latter approach in our view has eventually to come in conflicts with Physics.

Lemaitre [20] was the first to put the GR metric in relationship with a relative wavelength redshift in the observed light emitted from a receding galaxy

$$z = \lambda(t_{em})/\lambda_{obs} - 1 \,. \tag{1}$$

The formula is justifiable under suggestion of a simple physical picture, in which a wavelength of a photon emitted from an atomic oscillator increases proportionally to the scaling factor $a(t)$ at the emission time t counted from "the Beginning" of Universe till the present time t_0 (which is about 14 Gyr) so that $a(t) = 1$. The wavelengths are characteristics of the atomic oscillators, the photon emitter and the detecting absorber.

In the Lemaitre concept, the expansion model is assumed to be valid in the wide range of wavelengths, including both cosmological and microscopic scales. Some authors prefer a treatment of the redshift in terms of a frequency shift due to photon's climbing a potential well, which is a physically different process.

Hubble's Law connects a galaxy recession speed v_r, the distance $d(t)$, and the redshift z with expansion rate

$$H(t) = \dot{a}/a = \dot{d}/d \,, \tag{2}$$

a function of the matter/energy critical density $\Omega(t)$. The latter, as was noted before, currently includes dark matter, dark energy, neutrino, radiation, and a few percent of ordinary matter, all to account a quite sophisticated way

$$H(t) = f(\Omega, z, H_0) \,, \tag{3}$$

where $H_0 = 67.6$ km/Mps is the Hubble's constant. The equation (3) expresses the instructions for observational testing of the SCM.

Determination of absolute scalings of units from observations is the main problem of observational Astronomy and Astrophysics. The relative luminosity plays an important role in a calibration of distances d and times and assessments of Ω, z, and recession speed values.

The problem of the cosmological redshift in the SCM.

At small z, observations show linear dependences between z, d, and v_r, similar to that known from the kinetic Doppler effect. For a larger z, the used concept of the cosmological redshift z is drastically different from that in Classical and Relativistic theories.

In Astronomical observations of atomic linear spectra (first of all, the pronounced hydrogen Lyman-alpha line used in observations at $z > 2$, a precision worsens with z, what makes a determination of the space-time scaling problematic. At some $z \approx 6$, the Lyman-alpha line becomes shifted to the infra-red (invisible) range, and the redshift is assessed from the blue portion of optical spectrum having very little luminosity compared to the red light portion. The galaxy appears to vanish or dropout in blue light. The line spectrum is severely spoiled by high temperature thermal Doppler spread and clouds of gas and dust, which stars are wrapped in. Originally emitted photons, while coming through, have to be absorbed and re-emitted numerous times before a free flying and finally being collected by a telescope in a long exposition regime. Technological advance in methods of observations is of great importance for the precision improvement in fuzzy image observations.

The treatment of the redshift is based on a model dependent reconstruction of an evolution of the observed galaxy and its stars from highly diffused images. From the final database, the images are unfolded by a computer code following the criteria of fitting the observations to the Model (3). Details of high z observations are available in literature, e.g. [21, 22, 23, 24]. It is unknown how far the obtained effective value of z and the corresponding time-distance scales deviate from the true physical values (the term "true" is used in a sense of interpretation of observations in the physical framework based on the Fundamental Physical Principles with no New Physics).

We doubt a validity of the above formulation of Hubble's Law, firstly, in part of its non-physical redshift observables z related to the Dark Matter, Dark Energy, secondly, in part of the non-physical GR metric of expanding Universe. The Hubble's Law composition (3) is claimed to be derived from the FLRW metric being the EFE solution. The latter involves the GR mathematical formalism and Einstein's methodology of the curved space-time as the gravitational force manifestation. This multi-facet issue has to be separately analyzed in details, as in the following.

3.3 Review of mathematical aspects of the Standard Cosmological Model

The EFEs and the energy-momentum-stress tensor.

In the SCM, the space expansion metric is considered the exact solution to the Einstein's field equations. Let us outline the main known facts about the EFEs and their exact solutions.

The EFEs are differential non-linear equations in form of second rank tensors, namely, the Ricci curvature tensor $R_{\mu\nu}$, the metric $g_{\mu\nu}$ with Λ, the cosmological parameter, on the l.h.s., and the source, the energy-momentum-stress tensor $T_{\mu\nu}$ on the r.h.s.

$$R_{\mu\nu} - \frac{1}{2}Rg_{\mu\nu} + \Lambda g_{\mu\nu} = T_{\mu\nu}\,. \tag{4}$$

The tensor $T_{\mu\nu}$ is constructed phenomenologically so that the EFEs exact solutions have to be consistent with the all kind of its contributions from matter and fields.

This leaves a certain freedom of choice after phenomenological and mathematical constraints are imposed. It should be noted that the Ricci manifold is contracted from the Riemannian manifold, which is more rich in characterization of space-time curvature. For example, when the problem is formulated in terms of Riemannian manifolds, it is found that, to the next order precision, Einstein's concept of gravity due to the space-time curvature (in particular, caused by a constant acceleration of the frame by a mechanical force) is not equivalent to that due to the Newtonian gravitational force [25, 26, 27]. However, the equivalence of the both types of acceleration is the essence of Einstein's gravity concept.

With the tensor $T_{\mu\nu}$ chosen, the serious methodological problems with finding the exact EFE solution arise. Firstly, the manifold property of "smoothness" conflicts with physical reality of finite material bodies and formulation of their initial and boundary conditions. Secondly, the is no general prescriptions to prove the existence and uniqueness of the exact solution to the EFE. This problem seems to be avoided by looking for the solution "compatible" with constraints imposed by some postulated "postulated" geometrical space-time structure. In Cosmological applications, the constraints follow from the Cosmological Principal "on the cosmic scales". Having this, one can look for all possible sources, which could provide such properties. As we know, those sources include "the ordinary matter", "the Dark Matter", "the Dark Energy", and all kind of radiation with contributions "to be empirically fit" (what is called above "bad New Physics").

GR manifolds, metrics, and geodesics from the generalized SR metric.

To understand the EFE problems, one has to study physical and geometrical interpretations of EFEs, both are supposed to be true. This is actually the multi-aspect historical issue to be discussed further.

The exact EFE solutions, in general, are Lorentzian Riemannian manifolds, which are the metric spaces, each of them is provided with metric and a Lagrangian varying with respect to the metric. Consequently, the metric gives rise to the geodesic equations, what is the goal of the solution. At this point, it is important to emphasize that the GR metric in the most general form is considered a generalization of the Minkowski flat metric (a diagonal metric tensor) in Special Relativity.

In the SR Kinematic dealing with the coordinate (observable) time-like flat space-time, the metric quadratic form (in polar coordinates with the unit speed of light, is given by

$$\mathrm{d}s^2 = \mathrm{d}t^2 - \mathrm{d}r^2 - r^2\mathrm{d}\theta^2 \,. \tag{5}$$

The metric is obtained by means of Lorentz transformations from the proper space-time, which is characterized by the time variable $\tau(t)$) being the affine parameter in the world line interval $\mathrm{d}s = \mathrm{d}\tau$ connected to the coordinate time t.

The GR generalization assumes that the space-time is a curved 4-space so that off-diagonal terms in the metric tensor $g_{\mu\nu}$ can have non-zero values:

$$\mathrm{d}s^2 = g_{\mu\nu}\mathrm{d}x^\mu \otimes \mathrm{d}x^\nu \tag{6}$$

where $\mathrm{d}s = c_0\mathrm{d}\tau$. The GR geodesic equation in a general form is derived from (6) via the action principle

$$S = \int \mathrm{d}\tau \,, \tag{7}$$

then

$$\frac{\mathrm{d}^2x^\beta}{\mathrm{d}\tau^2} + \Gamma^\beta_{\alpha\nu}\frac{\mathrm{d}x^\alpha}{\mathrm{d}\tau}\frac{\mathrm{d}x^\nu}{\mathrm{d}\tau} = 0 \tag{8}$$

with Levi-Civita connections (the Christoffel symbols) $\Gamma_{\alpha\nu}$.

Here is the problem. The equation (8) is derived from the metric (6) defined in the abstract proper space-time that is, with the time variable τ having no connections with t in the coordinate space-time. The metric cannot be used for a derivation of geodesics in a coordinate system of observables with the time variable t. Moreover, the GR space-time metric itself does not contain the Universal Gravitational constant G. The question arises how it comes in a geodesics (8) derived from the metric. The G constant can actually appear in the tensor $T_{\mu\nu}$ of the EFEs, but this is another problem discussed further.

Components of the tensor $T_{\mu\nu}$, and the pseudo-tensor of the gravitational field $t^F_{\mu\nu}$.

The stress-energy-momentum tensor $T_{\mu\nu}$ has two parts, the matter $T^M_{\mu\nu}$ and the field $t^F_{\mu\nu}$, the sum of them determines conservative field properties. It must be thought phenomenologically constructed for the known fields such as in hydrodynamics, electromagnetic theory and the like, except for the genuine gravitational field, – call it the G-field, where the fundamental gravitational constant G is introduced in Newton's law of universal gravitation.

The problem of the EFE gravitational field model is that the field part is not a tensor. It is a pseudo-tensor needed to ensure the conservative field properties independently of a coordinate system. Einstein understood this problem and tried to find a satisfactory solution. Eventually, it was constructed purely from the metric by Landau [28]. At the same time, the GR geodesics remain associated with the coordinate systems defined in the proper space-time.

In [18], the pseudo-tensor term is thoroughly discussed as well as the fact that the GR concept of "gravitational field" is not rigorously defined and the theory is not compatible with the Special Relativity. The fact that the GR concept of gravity is estranged from the physical phenomenon of Newtonian gravity is discussed further.

Einstein's interpretation of gravitational field

The issues of GR interpretation of the gravity as a space-time curvature in relationship with the EFE solutions, their metrics and geodesics can hardly be found in GR expertise literature. Their significance and interpretations can vary among authors, or plainly ignored. However, they are vitally important for understanding of the GR fundamental role in the SCM.

According to Einstein's treatment of the EFE in terms of space-time curvature, the gravitational field, the subject of the EFE solutions, is not exactly the Newtonian G-gravity but rather "the gravity" being a result of space-time curvature. In particular, the curvature can arise in continuous massive media in the presence of fictitious forces (typically, in classically non-inertial frames).

The statement that a gravitational field indistinguishable from Newtonian gravity is a version of the GR Equivalence Principle in relation to the particle behavior in any classically non-inertial frame. According to the GR theory, a non-flat metric generate a gravitational field in the form of space-time curvature rather than in terms of gravitational force, potential and kinetic energies, and other concepts of Newtonian or SR Dynamics. Recall, concepts of forces, kinetic and potential energies, and others from Classical mechanics are foreign bodies in the GR conceptual arsenal.

The question arises how the fundamental gravitational constant G appears in metric solutions. Clearly, it comes out by virtue of Einstein's Equivalence Principle and formal analogy of Einstein's "curvature gravity" to the Newtonian physical G-gravity. This means that genuine (Newtonian) Gravitational Physics is actually excluded from the content of the GR Gravitational Field Theory and replaced by the ill-posed concept of space-time curvature.

One should notice that the fictitious forces (or pseudo-forces) are actually real ones, they can produce work. On microscopic scale, they arise as reactions of electromagnetic forces due to solid body deformations when external mechanical forces act on a body in a state of motion by inertia. However, their treatment in gravity terms is irrelevant in any classical field theory. They do not use the concept of deformable body subjected to stresses. Instead, the point test particle probing a field of forces acting at distance is introduced. Consequently, there are no tidal, or fictitious forces, or stresses there. There is an ongoing search for a quantum carrier in the gravitational field theory, so far, with no results. We state that the problem cannot be resolved, in principle, in the conventional GR concept of gravity.

The types of EFE solutions, and the fundamental gravitational constant G

As was pointed out before, the EFE equations (the l.h.s.) are supposed to account for space-time curvature in a way compatible with the covariant conservative stress-momentum-energy tensor $T_{\mu\nu}$ (the r.h.s.), which is purely phenomenological. This constraint, being not mathematically formulated, must lead to solutions, which are Lorentzian manifolds. The goal is to obtain the Lagrangian geodesics for a given physical problem formulated in the form of test particle solutions bringing a compatibility of the both sides.

The unfortunate fact is that the EFE model of fields does not provide us with unambiguous instructions ensuring the existence, uniqueness, and classification solutions. Recall, the EFE equations and their solutions are defined in the abstract proper space-time manifold with the world line $s(\tau)$ and no specification of forces. In Cosmology and Astrophysics, the two types of the EFE solutions are typically looked for.

The first type of solutions, – the vacuum solutions, are obtained for $T_{\mu\nu} = 0$ leading to test particle geodesics. The Newtonian constant G is formally inserted in the metric or in the corresponding Lagrangian non-flat solution by analogy to the genuine Newtonian field. The problem of two or N isolated bodies of finite masses can not be considered in GR, in principle [26], hence, the Classical Newton's law of attraction of two bodies (or two Black Holes) $F = m_1 m_2/r^2$ is not derivable. In spite of this fact, approximate solutions of the problem of two BH collision with the gravitational wave emission are suggested and used in assessments of sensitivity of the waves detection, for example, in the LIGO facility.

The Schwarzschild metric with its geodesics is an example of a vacuum solutions for $T_{\mu\nu} = 0$ that is, for Ricci tensor $R_{\mu\nu} = 0$. Historically, Einstein first time derived the GR equation of Mercury's motion and its solution from the EFEs approximately in search for an explanation of non-classical anomaly.

Later, Schwarzschild derived from EFEs his diagonal metric with the time-like signature [+, -, -, -], ($c = 1$). In the polar coordinates, it is given by

$$\mathrm{d}\tau^2 = (1 - 2C/r)\mathrm{d}t^2 - (1 - C/r)^{-1}\mathrm{d}r^2 - r^2\mathrm{d}\theta^2 \,. \tag{9}$$

The metric is defined in the proper space-time under conditions of the spherical symmetric field geometry with some constant C in the coefficient $(1 - 2C/r)$. By virtue of derivation, the metric is purely geometric with no conceptual connections with such quantities as a momentum and an energy, as required in the Lagrangian technique. Those physical quantities appear by power of will when the constant is chosen $C = r_g/r = GM/c_2$ is chosen by analogy to the gravitational (dimensionless) potential $V(r) = r_g/r = GM/c^2$.

From the SR viewpoint, the GR metric has no physical meaning because the time variables τ and t belonging to different 4-spaces, are not conceptually connected. In the SR theories, proper and coordinate 4-spaces are connected via Lorentz transformations.

The second type of solutions are obtained for continuous uniform media are with the tensor $T_{\mu\nu} \neq 0$ given a freedom of phenomenological construction depending on a physical problem formulation. In a typical case of "a dust matter", the tensor is reduced to the stress component $T_{\mu\nu} = \rho u_\mu u_\nu$ with ρ, a covariant density, and the velocity $u_\mu = \mathrm{d}x^\mu/\mathrm{d}\tau$. In the current version of the SCM, this solution is used in the form of the FLRW space expansion metric as the main ingredient of the Hubble model with "fitting parameters". It describes the Universe in terms of the density Ω of ordinary and Dark Matter, Dark Energy, and radiation in connection with the space-time scales, where the time t is actually the rescaled "observable" redshift z having nothing to do with the types of redshifts known in Physics. It should be noted that the Universal Gravitational constant G is a common multiplier in the Ω.

What coordinate system the GR testable predictions are made in?

As a result of detailed study of the EFE applicability to Cosmology, we reveal numerous inherent contradictions associated with the above question. The conclusion is made that the problems have a common cause manifesting the fundamental problem. The root of it is lurked in the EFE field model reflecting the ill defined gravity concept in terms of space-time curvature. These GR foundation premises lead to the conflicts between "the geometrical" l.h.s. and "the physical" r.h.s. of the EFEs and the subsequent chain of controversies and contradictions in observation treatment. Methodological connection of GR with the SR theory, which truly revolutionized the Physical Science, is completely lost. The manifolds are defined in the proper space-time with no connection to the coordinate time t, which is the time variable in the observable coordinate system.

To clarify this statement, we have to reiterate Einstein's gravity concept, as it is implemented in the EFEs, starting with a generalization the SR flat space metric. The generalization assumes that the space-time must be considered a curved space, hence, off-diagonal terms in the metric tensor $g_{\mu\nu}$ can have non-zero values (6). The latter is actually a definition of the proper world line interval τ in the proper coordinate system of the abstract proper 4-space. However, the corresponding quadratic form contains the coordinate time interval dt, which characterizes the observable (Minkowski) coordinate space-time. The problem comes from the fact that the transformations of the two spaces in GR are not defined that is, the time variables τ and t are conceptually disconnected, as in the example of the Schrarzschild metric (9).

Thus, the GR metric is defined in the abstract proper space-time, and so are the EFEs. One has to conclude that, in the GR Particle Dynamics, Lorentzian manifolds and geodesics obtained from EFEs are defined in the proper space-time that is, with the time variable τ. In GR practice, the τ is replaced with t with some vague or no comments. In the Schwarzschild Dynamics equations, both time variables usually appear when τ is often arbitrarily treated as "the comoving observer's time", though with no transformations to the coordinate 4-space system.

The imaginary observer in the proper 4-space, by definition, does not communicate with a real physical world, she "observes" nothing but the world line. Real Astronomical and Astrophysical observations are conducted in the coordinate systems of SR Kinematics and Dynamics with the time variable t. The reference frames with the variables τ and t are conceptually different, hence, not replaceable in any circumstances. The mismatch occurs at the fundamental level of EFEs formulation and their solutions.

In GR literature, it is a habitual tendency to avoid fundamentally important issues such as Einstein's interpretation of space-time curvature with the insertion of G in equations, the incompatibility of GR with the SR theory, and the replacement of τ by t in the equations of GR Dynamics.

3.4 Concluding notes

One can expect that the GR gravitational field theory (or any new field theory) would lead to a deeper understanding of physical meaning of the universal gravitational constant G and the related concepts of inertial versus gravitational mass. Ideally, explanation is desired in terms of gravitational force carriers, in analogy with Relativistic Quantum Electrodynamics. This is not principally possible in the GR methodology of curved space-time as "manifestation of gravity".

Einstein's concept of gravitation as a space-time curvature is actually associated with classical inertial forces having nothing to do with Newtonian gravitation. Formally, it is seen from the pseudo-tensorial character of $t_{\mu\nu}$ for "gravitational field", also, from a definition of the EFE Field Model formulated in the abstract proper space-time with no connections to the coordinate space-time of observables. Consequently, the Newtonian constant G cannot be organically embedded in the Model. Instead, it has to be inserted in the metric or the EFE solutions "by analogy" with Newtonian Physics (as made in cases of "vacuum (Schwarzschild) solution" and in "the metric of space expansion").

Not surprisingly, GR foundation premises lead to conflicts between "geometrical" and "physical" interpretations of the theory and a chain of controversies and contradictions in treatment of GR observables. As a result, the GR based interpretations of observables in the Standard Cosmological Model do not reflect the real physical world studied by Astronomy and Astrophysics.

In addition to the damaging role of the GR methodology in cosmological applications, an acceptance of the SCM is heavily aggravated by the pure-mind abstract idea of the singular Beginning with the following Inflationary scenario. Understandably, many attempts are made to "modify" the Model or find its alternatives, so far, without success.

In this work, we challenge the known statement that Newtonian Physics of Gravitation cannot be generalized in terms of SR Particle Dynamics, and demonstrate the validity of SR Gravitational Dynamics on the macroscopic and cosmological scales. This opens the room for our Alternative Cosmology and its connections with Modern Physics branches.

4 Special Relativity Kinematics and Dynamics

4.1 Mass, time, and clocks in the SR theory

The Special Relativity theory was briefly discussed earlier in connections with its Cosmological applications. Here, its basics are presented.

SR Kinematics is an approximation of the more general theory of Special Relativistic Dynamics. SR Kinematics is devoted to the Lorentz transformations of inertial coordinate systems in a relative motion of the test particles in the flat Minkowski space-time. The essence of the transformations is to ensure the constancy of the speed of light and, at the same time, to preserve the Euclidean concept of relativity of inertial motion so that a particle cannot move faster than light.

By definition of inertial system, the test particles do not interact with each other and do not create fields affecting the sources. The test particle concept is also introduced in Classical Field theories in connection with the concept of Potential (the Newtonian Gravitational Potential of a material sphere, for example). There, the field originated by massive bodies at rest is statically "probed" by the standard test particle in spatial points.

In the SR Theory, the test particles are considered the standard massive oscillators playing a role of the emitter and the detector of photons of the proper frequency f_p proportional to that of the oscillator. The corresponding oscillation period is $\Delta\tau_p = 1/f_p$. In the operational language, the observers are provided with the synchronized standard clocks used to communicate with each other. In other words, they exchange information by sending and receiving the standard photons, – short "light flashes".

Consider the observer O_1, who detects two sequent flashes on *her wristwatch* indicating the proper time interval $\Delta\tau_p = \tau_{(i+1)} - \tau_i$. Let the second observer O_2 move along the trajectory $s(x^\mu)$, which is tracked by rest clocks of O_1, so that *her clocks* detect a pair of flashes from O_2 indicating the *improper* time interval $\Delta t = t_{(i+1)}(s_2) - t_i(s_1)$.

We see how the observer's proper time τ_p operationally becomes the improper time t (called the coordinate time), when the observer starts observing the physical world. The important fact must be realized that all "standard (atomic) clocks" at rest show the elapse (proper) time, which tells nothing until it is compared with records of other standard clocks at rest or in a relative motion. In this way, the time τ becomes connected with the coordinate time t, which is recorded by, at least, a pair of clocks (there are no single clocks recording the coordinate time t).

Mathematically, the Lorentz transformations of the coordinate systems perfectly project the abstract 4-space onto the relativistic space-time observable in reality. We have two different scales of τ_p and $t = \gamma\tau_p$ connected by the Lorentz factor γ, as follows from the Lorentz transformations. The *apparent* retardation of a clock observed in motion is the known relativistic time dilation effect, the result of comparison of the proper time unit $\Delta\tau_p$ recorded by O_i wristwatch at rest and the measured Δt_i of O_j at a relative motion with respect to O_i. Obviously, indices i and j are symmetric so that any observer measures its own *proper time* unit $\Delta\tau_p$ and any other observer's *coordinate time* unit Δt in comparison. Still, questions about how to correctly conduct and interpret the observations of the real non-classical world are disputed in literature [29, 30].

4.2 The conventional SR Dynamics

In SR Dynamics, fields of forces are introduced in isolated (insular) systems. As a distance from the system center becomes however great, a field strength tends to vanish. Here, we are interested, first of all, in the gravitational field due to the massive source. The proper time interval $d\tau_p$ is the temporal part of the 4-space, which is the Minkowski non-flat space-time that is, "curved" by the field.

The test particle of proper mass m_p is considered the quantum oscillator with the frequency f_p proportional to m_p. The latter is the field dependent temporal part of the 4-Minkowski space. Consequently, the proper time period of oscillation $d\tau_p = 1/f_p$ as well as the Lorentz factor γ are dependent on the field strength.

In the first place, one needs to introduce the concept of a world line $s(x^\mu)$ in the metric quadratic form in the proper spaces with the proper time interval $\mathrm{d}\tau_p$ and the proper mass m_p

$$\mathrm{d}s^2 = c_0^2 \mathrm{d}\tau^2 U_\mu U^\nu \,. \tag{10}$$

with a usual convention $c_0 = 1$, and the proper unit 4-vector $U^\mu = \mathrm{d}x^\mu/\mathrm{d}s$ tangential to the line, so that the metric tensor is diagonal:

$$U_\mu U^\mu = 1, \quad U_\mu(\mathrm{d}U^\mu/\mathrm{d}\tau) = 0\,. \tag{11}$$

A proper 4-coordinate infinitesimal displacement $\mathrm{d}x^\nu$ of the line in the proper 4-coordinate space x^μ is defined in connection with the proper 4-momentum (complementary) space P^μ through U^μ:

$$\mathrm{d}x^\mu = \mathrm{d}\tau_p(x^\mu)U^\mu, \quad P^\mu = m_p(x^\mu)U^\mu\,. \tag{12}$$

The relativistic SR Dynamics quantities can be defined in terms of the proper Minkowski (4-vector) force, in particular, the radial one

$$K^\mu = \mathrm{d}P^\mu(s)/\mathrm{d}s = m_p(x^\mu)[dU^\mu/ds] + U^\mu[dm_p(x^\mu)/ds]\,. \tag{13}$$

The crucial point is mapping of the proper spaces onto the coordinate spaces of observables by means of Lorentz coordinate transformations. The metric with the quadratic form $\mathrm{d}\tau^2$ *is transformed into the Minkowski (non-flat) metric with the quadratic form* $\mathrm{d}t^2$.

In the conventional SR theory, as well as in GR Dynamics, the proper mass is constant. This is considered a weak field approximation, after Synge, [31], who developed the theory accounting for the proper mass variation but thought the effect be practically negligible. This point of view is widely accepted among workers on Relativistic Mechanics applications. Strictly speaking, however, to consider the proper mass constancy an approximation would be methodologically wrong, because the values of $\mathrm{d}\tau$ and m must be inversely proportional due to the complementarity of $\mathrm{d}x^\mu$ and P^μ. The history of this issue and the consequences of the approximation are discussed in [32], also see [33].

4.3 The SR Dynamics with the field dependent proper mass

One can think that changes of physical unit gauges in cluster hierarchy would make interpretation of Astronomical observations ambiguous. However, we cannot and do not directly compare rates of atomic clocks (quantum oscillators) at distance. Instead, we use information from the exchange of photons, physical properties of which can be defined differently to make interpretations consistent depending on a theory. So the so-called gravitational time dilation, and the gravitational redshift are accounted in all theories. Here, we discuss those and similar effects in more generality at the level of SR Dynamics.

In the spherical symmetric field, the field dependent proper mass is

$$m(r) = m_0 \exp(-\rho_0/r) \tag{14}$$

where $m_0 = m(r)$ at $r = r_0$ (the radius fixed in the initial conditions $\rho_0 = r_g/r_0$). In the case of a not bounded particle, the initial conditions are defined "at infinity", $r_0 \to \infty$.

The corresponding coordinate time interval is given by

$$\Delta t(r) = \Delta t_0 \exp(\rho_0/r) \tag{15}$$

The following scalar product is the conserved (squared) value of the 4-phase vector

$$P^\mu \cdot \Delta x_\mu = m\Delta t \tag{16}$$

as is seen from the Einstein-de Broglie relationship. There, a period of a quantum oscillation is related to the frequency, both field dependent

$$mc_0^2 = h\,f, \quad \Delta\tau = 1/f\,, \tag{17}$$

where h is Planck's constant, $c_0 = 1$, $m_0 = 1$. Next, we take $\mathrm{d}t = \Delta t$ to be a however small period of the standard quantum oscillator in the Einstein-de Broglie formula (17).

4.4 Lorentz transforms of the proper 4-spaces, Lagrangian technique, and SR geodesics

With a metric given, the Lagrangian can be formulated, hence, the total energy (the Hamiltonian H) found

$$H = \sum \dot{q}_i \frac{\partial L}{\partial \dot{q}_i} - L\,. \tag{18}$$

This would be the first step of connecting the proper (abstract) and coordinate (observable) spaces to get the SR Dynamics equations for treatments of Astronomical and Cosmological observations. First of all, we are interested in quantities observable in a spherical symmetric geometry.

From the Lorentz transformations of the proper 4-vectors to the coordinate 4-vectors (12), it follows:

$$\mathrm{d}t = \gamma \mathrm{d}\tau \exp\left(r_g/r\right). \tag{19}$$

and the Lagrangian

$$L = -\mathrm{d}\tau/\mathrm{d}t = -\exp\left(-r_g/r\right)/\gamma \tag{20}$$

to be used in the Hamiltonian Action Principle

$$\delta S = \delta \int_{t_1}^{t_2} L(q_i, \dot{q}_i, t)\,\mathrm{d}t = 0\,, \tag{21}$$

where $q_1 = r$, $\dot{q}_1 = \mathrm{d}r/\mathrm{d}t = \beta_r = \dot{r}$, and $q_2 = r\theta$, $\dot{q}_2 = \beta_\theta = r\dot{\theta} = r(\mathrm{d}\theta/\mathrm{d}t)$. The corresponding Hamiltonian is given by

$$H = \sum \dot{q}_i \frac{\partial L}{\partial \dot{q}_i} - L\,, \tag{22}$$

that is

$$H = \gamma \exp\left(-r_g/r\right). \tag{23}$$

This is the conserved total energy ϵ defined in the 4-momentum space in relationship with equations of motion in the 4-coordinate space. The conservation $\epsilon = \epsilon_0$ holds at any points

$r = r_0$, $t = t_0$ fixed at the initial conditions of dynamic equation solutions. It is convenient to fix it at $t = 0$, the values of $\beta_\theta = \beta_0$, $\beta_r = \beta_{r0}$ and $\gamma = \gamma_0 = (1 - \beta_{r0}^2 - \beta_0^2)^{-1}$

$$\epsilon_0 = (1 - \dot{r}^2 - r^2\dot{\theta}^2)^{-1/2} \exp\left(-r_g/r\right) . \tag{24}$$

The conserved angular momentum $l = r\beta_\theta$ is

$$l_0 = r\beta_\theta . \tag{25}$$

Similarly, we formulate the Lagrangian L_m in the 4-momentum space. Now the coordinate mass m_t corresponding to the coordinate time t should be considered different from the proper mass m_τ corresponding to the proper time time τ. They are connected by a physical relationship

$$m_t = \gamma \exp -(r_g/r) m_\tau . \tag{26}$$

The corresponding Lagrangian L_m is

$$L_m = -m_\tau/m_t = -\exp\left(r_g/r\right)/\gamma \tag{27}$$

giving the Hamiltonian

$$H = \gamma \exp\left(-r_g/r\right) . \tag{28}$$

Now we have the conserved time interval $\Delta t = 1/f$, which is a time elapsing between two ticks of the standard clock. This quantity is defined in relationship with the 4-coordinate space. Its conservation $\Delta t = \Delta_0$ holds at any points $r = r_0$, $t = t_0$ fixed at the initial conditions of dynamic equation solutions.

It should be noted that the magnitude ψ of the 4-phase vector is conserved too:

$$\psi = \sqrt{m\Delta t} = \gamma = \gamma_0 . \tag{29}$$

Notice, the SR Lagrangian is constructed from the temporal parts of the 4-vectors in the 4-coordinate and 4-momentum spaces in their relationship with the corresponding 4-vectors in the proper spaces. The Lagrangian returns the SR Dynamics geodesic obtained from 4-vectors either in the 4-coordinate or 4-momentum space. A non-flatness of the SR metric in the presence of force field is accounted by the introduction of the field dependent proper mass. In SR terms, the non-flatness of metric can be considered a manifestation of the space-time curvature due to presence of forces, what is radically different from Einstein's concept of curved space-time in non-inertial reference frames.

The important fact is that the conservation laws follow from Noether's theorems associated with the symmetries of 4-spaces, namely, a material system is system isotropic in every direction, and the coordinate time t runs uniformly at every point of the Minkowski non-flat space including regions "at infinity".

The SR Dynamic equations of motion come out only after fixing the initial conditions. Main of the equations, in comparison with GR and Classical ones, are presented in the Section devoted to Milky Way.

5 Back to the GU Model in the SR Dynamics framework

This section is intended to complete explanations of observation in the proposed alternative GU Model based on the SR Principles, as opposed to the criticized above conventional GR methodology in the SCM.

5.1 Random Statistics in the collision scenario in the GU Model

Having the Lagrangian equations in SR Dynamic laid out, we want to complete the explanations of observations in more details accounting for a complexity of the TU collision.

While the GU Model is fully based on Fundamental Physical Principles, it does not mean that it must be based on "analytic laws" describing a deep past and a far future. This is basically due to statistics of randomness in complex scenarios of the TUs collision and their disintegration, especially, on the verge of space-time scales.

The complexity of the GU Model is essentially predetermined by dealing with a high-order ladder of matter clustering in the SR Dynamics, as discussed next. Consequently, a reconstruction of the GU image in full space-time volume from an extremely limited sample of the OU data has an inevitable limitation of confidence. In these new circumstances, one has to recognize the benchmark and mock-up observed events, which could be most informative for a radical reconsideration of the space-time scales currently established in the SCM.

A statistical search for a scientific truth is usually made by the well working method of trial and error within the Bayesian approach with data regression by the maximum likelihood criterion. A scientific intuition and logics of beyond customary imagination would be of primary importance.

5.2 The hierarchy of matter clusters

Gravitating matter naturally tends to cluster in a hierarchy of isolated systems known in the Observed Universe: a planetary system as a part of some galaxy, in its turn, a part of a galaxy cluster, likely, a part of a super-cluster. In the GU Model, there are more clusterings of higher order.

In the example of our (ideal) planetary system with the Sun's mass however greater than a mass of any planet $M \gg m$, we have the gravitational radius $r_g = GM/c_{inf}^2$ where c_{inf} is the speed of light at infinity (here, "infinity" is used as a physical term of however distant space but an issue of constancy of G, c and other physical constants do not discuss yet). So, what is the infinity?

Let us consider, in GR or SR Dynamics, the geodesic equation of point test particle motion in the Sun's gravitational field in the ideal spherical symmetric geometry with the Sun in the center of the coordinate origin [34, 35]. The particle will loose its connection with the Sun, if its total energy (in the dimensionless form) $\epsilon > 1$ at $r \to \infty$, formally, while practically, the radius should not exceed the size of our Galaxy, the Milky Way, the Sun belongs to. In this case, the infinity corresponds to the background of galaxy potential field. The next level of infinity will be the gravitational field background of the galaxy in the inter-galaxy space. Notice, the center of attraction in reality is the center of mass determined by all masses of the N-body bounded system.

In a real example of NASA Pioneer-10 mission to reach the interstellar space, the spacecraft had, firstly, to overcome Earth's gravity and, next, the Sun's gravity pull. This mission (as well as other similar ones) failed [36] in precision of interstellar space tracking, and an open question remains, – why. In perspective, with enough fuel for kinetic energy, it would climb the next potential well created by Milky Way.

In the GU Model, a full completion of mission would include the potential well of the TU in order to get to the GUB medium of minimal mass density (let us call it "physical vacuum" at the so far ultimate infinity). In accordance to the GU Model, the ultimate background or the ideal physical vacuum does not exist, what is somehow a strange statement if applied to a field theory.

5.3 Physical unit gauges in fields and in clustering hierarchy

As was emphasized, in the presented SR Dynamics masses of particles are exponentially dependent on a gravitational field strength. When thrown to infinity, a particle became unbounded, and its mass reaches a maximal value of first level in a sequence m_{0j}, $j = 1, 2, 3, \dots$. Atomic clock rates correspondingly change. Therefore, physical units (the meter, the second, the kilogram, and their combinations) must be field dependent in the hierarchy of clusters. In the conventional particle and field relativistic theories, masses of all particles are given the values observed in laboratories, and so they are fixed. In weak fields, the difference is of the order of field strength parameter, however, the introduction of field dependent proper mass makes a fundamental difference in physical concepts. The classical definition of potential energy $1/r$ becomes associated with the proper mass change or the mass defect in a nuclear energy science. Correspondingly, the known effects of gravitational time dilation and red-shift are considered consequences of the proper mass variation. Those effects are automatically accounted in SR Dynamics equations along with relativistic motion effects. As a consequence, the solutions are free from central infinities.

Now the question arises about constancy of the fundamental physical constants such as the gravitational constant G, Planck's constant h, electric charge e). We postulate that the above fundamental physical constants remain intact in our approach. For the light (a photon), the gravitational field serves as a refracting medium with the refractive index being field dependent. In the spherically symmetric geometry, it is a function of radius: $n = c_0/c(\rho) \geqslant 1$, where c_0 is the speed of light at infinity, $\rho_0 = r_g/r$ is the field strength. Hence, the speed of light in SR Dynamics must be field dependent that is, the electric permittivity and magnetic permeability vary in gravitational, electric, and magnetic fields.

Unfortunately, the exact form of the dependence remains subject to ongoing studies within relativistic quantum field theories. In the proposed GU model, we have to cope with the above issues in some speculative manner. In [37, 38], the effective refractive index in the Schwarzschild field is suggested in the form $n = (1 + 2\,r_g/r)$, $n = \exp{(2\,r_g/r)}$, what is allegedly confirmed in the light bending observations.

One can think that changes of physical unit gauges in cluster hierarchy would make interpretation of Astronomical observations ambiguous. However, the change of atomic clock rate in a potential field, and the gravitational redshift are accounted in all theories. Here, we discuss those and similar effects in more generality at the level of SR Dynamics.

In the GU Model, the impact of clustering hierarchy in determination of space-time scalings is the problem aggravated by a non-stationary process of the TU collusion.

5.4 Black Holes

We ignore the General Relativity concept of the BH phenomenon suggesting a matter collapse into a mathematical singularity point. Also, we ignore the so-called Astronomical BH concept with physical properties having nothing to do with the academic GR gravitational field theory (such as Hawking radiation, entropy, matter trap, information loss, and a lot more). Instead, we introduce a physical phenomenon, which naturally follows from the SR Dynamics with a field dependent proper mass resulting in the elimination of both coordinate and central singularities [39].

A central gravitational attractor could be of any finite size, and have any matter density not greater than that of nuclei's. This is what we observe in galaxy centers. The binding energy of the source is the proper mass defect $\Delta m = m(r) - m_0$, (14), which could be a large part of the rest mass at infinity. It could make an illusion of the missing mass (Dark Matter).

Our physical reasoning is actually in agreement with the Birkhoff's Theorem admitting the matter-filled internal solution of the Schwarzschild metric, also with the non-singular solution originally obtained by Schwarzschild himself [40]. Astronomical observations do not give a firm evidence of gravitational collapse. More comments on this and other "unusual" issues are given in the Appendix.

5.5 The redshifts, the Hubble's Law, and comparison of the two Cosmological Models

The redshifts, the Hubble's Law.

In the GU Model, the redshift is a physical effect involving photons emitted from an atom (a quantum oscillator), in a vicinity of a gravitational source. When it is detected by the observer using the same quantum oscillator at some distance away, the redshift effect is observed due to photon frequency shift. As mentioned above, the effect should be described in terms of a photon motion in a gravitational field considered a refracting medium with the refracting index being a function of radial distance from an emitter to the detector. In general, the phenomenon includes three types of a frequency shift of Special Relativity Dynamics, which are observable in vacuum.

1. *The SR Kinematics Doppler effect in photons from an emitter moving by inertia away from a detector with a constant speed.* The Doppler technique is routinely used in Astronomy, Astrophysics, and in commercial applications.

2. *The effect of suppressing a proper frequency of the oscillator-emitter in the local gravitation field.* The emitted photon moves with that frequency unchanged and thus is detected appearing red-shifted (or blue-shifted when moving in reverse direction). The effect is actually associated with the so-called gravitational time dilation, when the time interval being inversely proportional to the frequency is recorded properly changed. The speed of light propagation and the corresponding length-wave must vary in the field respectively to keep the shifted frequency unchanged: $f = 1/\Delta t = c(r)/\lambda(r)$ [41].

3. *The effect of a change of physical unit gauge.* We believe that this new effects plays an important role in observed redshifts. As emphasized, a TU collision in the GU Model is a quite complicated non-stationary process. It is actually not observed in its main part of the collision beginning. The highest redshifts are allegedly observed in the deep field surveillance by the Hubble's telescope.

The anomalies could arise due disturbance by some opaque media, e.g. caused by a photon passing through a chromosphere layer (a refracting and scattering medium) of gas and dust in TU stars. These redshift anomalies should be also considered.

Critical comparison of the SCM and the GU Models.

We criticize the Hubble's Law formulation in the SCM in terms of metric expansion with involvement of New Physics and suggests the alternative interpretation of observed redshifts bearing in mind that the value of observed redshifts are model adjusted (or effective) rather than physically real. They are reconstructed from the fuzzy images by the computer code predetermined by the Hubble's Law governed by the GR metric expansion of space.

In the SR Dynamics framework the physical value could be appreciably less. So far, in the GU Model no specific criteria of quantitative description is suggested because of complexity of the observed picture of the TU collision. Given the GU model concept, further studies involving teams of specialists are needed.

The picture of receding galaxies in some way is analogous to a slow bomb explosion in a relatively large volume of TU collision with fragments (galaxies) flying away by inertia during a long period of time. The survived part of the bigger TU is the place we live in, from which a surveillance of the expanded volume much greater than it was at the beginning is conducted.

Distances to observed galaxies should be assessed in the Special Relativity framework with the use of the Minkowski metric. The latter is characterized by light-like and space-like intervals with respect to the imaginary Observer at the origin of the coordinate system that is, at the Beginning point, the center of mass of the colliding TUs. Let us be the Observer.

To understand the idea, let us take the distance r scale in Gly units, and the coordinate time in Gyr units be counted from right now moment $t = 0$. Assume that the peak of collision activity occurred 5 Gyr ago, $t = -5$, at the place of Observer's location $r = 0$. For simplicity, assume the speeds of recession appreciably less then the speed of light to consider the problem in the Newtonian limit.

Our Observable Universe is seen now as a static picture of galaxies located in the whole range of distances r, from which the light comes. On average, they are thought being seen in some orderly manner: with the greater r, the smaller luminosity L, and, very roughly, the higher redshift z and the receding speed β, with no strict correlation of r, L, z, β. There is a practical limit at $r = R$ where $L \to 0$ (in the SCM, where the effective redshift $z \leqslant 10$).

Recall, the Observable Universe is defined at $t = 0$. Because galaxies are flying away, they are located right now at distances $r\prime > r$ depending on β. Let $r = 5$ and $\beta = 0.1$ at a maximal $r = R$. Then, the radial shift will be $\Delta r = 0.5$ what is relatively small in comparison with $R = 5$ in the picture of instant snap. In this thought variant, Our Observable Universe exits about 10 Gyr, since the exploding collision, in analogy with the Big Bang. The radical difference between the two models is in the interpretation of the Observable Universe.

The Observable Universe looks like made by the instant snap camera, and is a small part of the Universe history. The Universe, which existed at the time period $-0.5 < t < 0$ in the state of collision is not observable. Even less hints there are about what had occurred before the collision $t < -0.5$. Likely, we can predict something definite about the nearest future $t > 0$.

The problem with the time-scale determination is aggravated by the change of clock rate of the Observer due to the change of physical unit gauges. Now we are talking about the change of wristwatch frequency of the Observer, that is, the standard atomic clock frequency of the photon detector. It could happened in past that, while the space around the Observer was voided of the matter, the surrounding matter could start mowing away still having a great density and been bounded for this account. Then, given atomic clock frequency of the photon emitter, the Observer's clock would run faster so that the light coming from the flying matter, would appear additionally red-shifted due to the greater potential well. The situation with clocks changes, depending on the collision scenario.

The suggested Alternative Model is formulated in the form of a challenging unfolding problem in the Science of Physics. One has to work with the observed picture serving as the input for the code to be composed from the Model description, that is, the information on physical laws, mathematical equations, and the corresponding database determining the most probable scenario of evolution of the explosion in the GU concept. This is the human mind quest for understanding at a new level the Nature of world we live in.

Quite opposite, in the SCM, Observable is, basically, readily made the whole Universe in its history of observations, from the instant appearance to the ultimate disappearance.

5.6 The role of SR methodology in the GU Cosmology

Significance of the SR concept of field dependent proper mass.

As was noted, the conventional SR Dynamics admits the proper mass constancy. Yet, it is wrongly considered not applicable to the gravitational field problems. These unjustified restrictions are aborted in our methodology. The SR framework with the concept of field dependent proper mass (14) constitutes the GU methodological basis, that makes the Cosmological picture drastically different from that in the SCM. We state that an implementation of the SR concept of field dependent proper mass is required to preserve the complementarity of coordinate and and momentum 4-spaces. Also, it is vitally needed for further developing and deeper interconnecting of Modern Physics branches, such as Cosmology, Quantum Electrodynamics, Particle Physics, Relativistic Quantum Field Theories, in general, first of all, for solving the long standing problem of the gravitational field.

Infinities and renormalization.

The infinity curse and its remedy,- an artificial mathematical procedure of renormalization, needs to be conceptually apprehended and finally eliminated [28, 42, 43, 44]. Dirac did not accept infinities; he commented about the normalization "in theory neglecting infinities which appear in its equations, neglecting them in an arbitrary way. This is just not sensible mathematics. Sensible mathematics involves neglecting a quantity when it is small – not neglecting it just because it is infinitely great and you do not want it." [45, 46].

In general, the field dependent proper mass (14) is to be incorporated, as the unalienable property of the relativistic coordinate and momentum spaces. The exponential factor determines the relativistic gravitational dilation effect statically and dynamically, otherwise, it could not naturally appear in equations of motion and conservation laws [32, 47].

Quantization and unification problems.

The normalization problem goes hand in hand with the problem of quantization. The introduction of the de Broglie wave concept (17) in the SR Dynamics is the first step to resolving the quantization problem.

In the equation $m\,c_0^2 = h\,f$, both quantities m and f are field dependent temporal parts of the 4-phase vector describing the standard particle being quantum oscillator. From the spatial part, the de Broglie wave concept λ follows $p = h/\lambda$. Once the field dependent proper mass is introduced, one can see a similarity of introduction of the relativistic mass concept in the important cases of the $1/r$ potentials of gravitational and Coulomb spherical symmetric systems of particle motion about the attractor. This might be a clue to the unification of gravitational and electric forces [48].

6 Discussions of the comparison

6.1 The succession of Physical knowledge, and the Philosophy of truth

The SCM, as a part of Modern Physics, historically does not respect a succession of Physical knowledge. Cosmology must be considered the most general Physical Science, the quest for comprehension of physical world at the deepest level, and as such, it is a reflection of historically accumulated knowledge constituting Foundations of Physics. One can take a brief look at a history of contemporary Physics to argue how lessons have been learned as of today, and what would be in future.

The 20th Century revolution in Physics with an advent of Special Relativity theory (by Einstein, Lorentz, Poincaré) has resulted in a radically new understanding of Classical Mechanics and Maxwellian electromagnetism. This transition to the new world-view was neither sudden nor smooth: there are still controversies and paradoxes, which are caused by a lack of opponents' understanding of the basic fact that the Special Relativity Kinematics is an approximation of motion in space-time free of forces. The motion in the presence of any type of forces is subject to Special Relativity Dynamics, development of which historically encountered methodological difficulties. Some of the fundamentally important problems remain unresolved, for example, the infinity problem.

In parallel, Quantum Mechanics has been developed classically (by Heisenberg, Schrödinger), and later semi-classically (by Dirac). It still lacks a full consistent implementation of the SR Dynamics Principles defined in the coordinate and momentum 4-spaces. Consequently, a development of the electromagnetic field theory has not been completed.

At the same time, the transition from the world-view of Newtonian Gravitational Physics to the Einsteinian General Relativity world-view was proclaimed but, strangely, with the General Relativity theory being estranged from the Classical and Modern Physics Fundamental branches, including the Special Relativity theory. This is equivalent to the departure from the empirical basis of Classical Newtonian and Relativistic Mechanics. As a severe consequence, the theory of relativistic quantum gravitational field in connections with Particle Physics came to the scene as a long-standing unresolved problem.

We consider the current Standard Cosmological and Particle Models phenomenological models deprived of the Physical Foundations. Incompleteness and misconceptions of methodological implementations of Fundamental Physics Principles are the reality of Modern Physics crisis, without recognitions of which the genuine nature of "gravity", "mass", "electricity", "charge", "spin", "physical vacuum", "quantum carrier of force" in their physical unity of quantum relativistic theories can never be unveiled.

Thomas Kuhn, philosopher and historian in natural Sciences, in his book [49] introduced the conceptual term of Paradigm Shift, which was rightly criticized in literature. However, for descriptions of scientific revolutions, this is a good term to apply to Modern Physics in a sense that the paradigm shift could be a real revolution, as happened with SR theory appearance. A fictitious revolution is usually promoted by the main stream, as the revolutionary GR world-view, which we consider a descent in Dark Ages.

Acceptance of an incomplete or even false theory is a normal and seemingly unavoidable occurrence in Physics history. Kuhn gives a quote in his book (p. 150) from Max Planck: "A new scientific truth does not triumph by convincing its opponents and making them see the light, but rather because its opponents eventually die, and a new generation grows up that is familiar with it". However, this expectation does not seem quite realistic. Over time, the main stream could strengthen and triumph its power of protecting dogmas and suppressing novelties, eroding the past knowledge and disseminating the scientific noise, – until the cry of evidences for physical reality different from exhibited could be heard, but would it?

The Standard Model of Particle Physics after the Higgs' discovery enjoys the state of perfect fit, which is considered by theoreticians a state of uncertainties, perplexity, and disappointment because of the failure to comprehend the Nature and the Universe origin from the first principles. Good New Physics from microscopic and cosmic perspectives has not come, and the door to gravitational field problem remained locked, the time is given for rethinking the problem from scratches [50, 51].

Still, suggestions of the post-Higgs revival are coming, which include a continuation of the search for signs beyond the Standard Model on the running LHC and new machines to be built. They are old thoughts persisting to explain the GR and Big Bang picture of Nature with no slightest doubt if the picture is real.

The main historic lesson one can formulate in the concise form is: Cosmology and related branches of Modern Physics are in deep crisis. This fact is actually admitted, however, it is seen differently by leading field experts. In Cosmology, Gravitational Physics, and related theories, bad New Physics is agreeably admitted with a hope for the better choice to seek for, [1, 2, 52, 53, 54]. A resistance to acknowledge the fact has to be overcome.

6.2 Why the GU Model

In the GU Model is a radically new Model, in which the long-standing problems of matter-antimatter and Cosmic Rays are recognized as the Cosmological problems and explained for the first time. The Model explains all basic cosmological observations with no appeal to bad New Physics. The Grand Universe Model, unexpectedly, reconciles or re-views in a certain way physical ideas having a common sense in the alternative theoretical models and theories:

- Matter-Antimatter symmetry (the Plasma Universe);
- Space expansion from the beginning (Lemaître's primeval atom in the Big Bang);
- Continuous matter recreation (Steady State Cosmology);
- A general idea of multiple Universes in different cosmological versions;
- The concept of cosmological background in relativistic field theories;
- The cosmological change of fundamental physical constants.

The GU Cosmological Model has an explanatory and predicting power owing to its conceptual methodology based on Principles of Fundamental Physics and SR Dynamics. It gives a physical explanation of the Universe expansion and its beginning. Now we can avoid the SCM with its miraculous Beginning, and the bad New Physics.

The GU Model is constructive, since questions are formulated in the form revealing the roots of certain unsolved problems and clues for their resolutions. There is a fresh look at the long-standing problem of gravitational field theory.

The GU Model is enlightening, since physical issues are raised in greater generality to the extent, where validity of Fundamental Physics Principles become questionable. It opens new space for deeper exploration and comprehension of the observed physical world in the eternal process of succession of knowledge about Uniqueness of Physical Nature.

This paper carries a positive message to rethink over the beliefs in validity of theoretical models, concepts, and statements of principal importance. The important role of Modern Philosophy in critical analysis of Modern Physics theories in their unity reflecting the Unity of Nature, and verifiability by the criterion of True Nature is emphasized. The GU Model matches the philosophical concept of methodological naturalness currently propagated in Modern Physics theories and models.

We hope, scientists in Natural Sciences and Philosophy will read the paper with interest and respond with both critical and constructive comments concerning Modern Physics problems in relationship with the Alternative Cosmology.

In the Appendices, the SR Dynamics methodology is illustrated in comparison with Classical and GR methodologies, all applied to the Milky Way observation data in the GU scenario of two TUs collision. The MW physical characteristics, including the issues of Black Holes, Dark Matter and antimatter, are discussed in the context of the GU Model. The results of exact solutions of model equations describing a motions of stars in the central region of Milky Way are presented. Materials are illustrative, since the detailed analysis of the corresponding observational database is out of the scope of the present work.

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Appendices

A The Milky Way in the GU Model

A.1 The Milky Way before and after the collision

Our galaxy, the observed Milky Way (MW), is of type of a spiral disc with a massive attractor, the Black Hole (BH_{mw}) at the center surrounded by a bulge [55, 56, 57]. There is no any proven indication of the BH_{mw} gravitational collapse. It is possible in the GR theory but could not happen in the SR Dynamics; yet, its physical reality is arguable in literature, [58, 39]. So, we use the term of BH for a central gravitational source, which has a finite size, and a mass density not exceeding that in the neutron star.

In the collision scenario, the age of the observed MW galaxy could be approximately assessed provided random statistics of the complex history taken into account. Likely, the galaxy before had existed in some mature form before the collision of the two TUs. It is reasonable to suggest that the original MW was old enough when has reached a state of maximal mechanical stability. Such a state requires optimal conditions of reconciling an extreme binding energy, on the one hand, and the extreme angular momentum, on the other hand. Then, a system of stars could rotate about the central attractor of a great mass and density, while the stars comprised a thick galaxy disc and had orbits characterized by minimal eccentricities with no bulges, no spiral arms.

The observed MW structure was developed during the collision when the galaxy was significantly washed out by antimatter, but it survived in the currently observed crippled state. Indeed, the BH_{mw} is seen having the mass appreciably less then the rest of the galaxy. The original BH_{mw} was destructed during the collision, the bulge formation is one of the consequences.

Likely, the BH_{mw} mass was about two orders greater than at present; the total mass of stars was greater as well, the MW was a strongly bounded system. After the collision, the binding energy significantly decreased while a great amount of matter lost. This made the MW system dynamically unstable so that spiral arms were formed in the weakest parts of the disc.

A.2 Dark Matter and antimatter

It is right to think that the current MW as a whole must be supported by additional gravitationally interacting material, at least, in the central area. This is how the idea of "Dark Matter halo" came to explain the observed picture of the Milky Way and other spiral galaxies. In particular, it is argued that the observed rotational curve cannot be explained by the Newtonian (Keplerian) model of orbits without the Dark Matter hypothesis. Recall, in Classical Mechanics, orbits describe the test particle motion of however small mass in the spherical symmetric gravitational field due to a central source. The alternative explanation in GU Model comes from the matter-antimatter collision scenario.

The observed MW galaxy is characterized by specific radial mass density distribution in spiral arms and noticeable disc rigidity due to a gravitational interaction of stars. Yet, the observations show their rotational curve being flat. We state that the observations cannot be described by an analytic model like the Keplerian one. The correct description requires a complex model accounting for the MW characteristics with the use of numerical calculations. Some authors insist that the flat rotational curve can be also explained in a simplified approximate model with some additional assumptions about the galaxy physical structure, [39, 59]. We state that, in view of the collision scenario in the GU Cosmology, the Dark Matter argument is a misconception.

As was noted before, Astrophysical observations reveal strange phenomena, which we consider an evidence of antimatter presence in the MW and some other galaxies. In particular, it concerns often events of high intensity flares in the central MW part, also, unexplained physical properties of the BH_{mw} [60, 61, 62, 63], also, huge X-ray busts in some other galaxies [64, 65, 66].

A.3 The Milky Way center observations and treatments

Observations

Since 1992 the center of the Milky Way galaxy has been observed by several research groups. As a result, many Keplerian stellar orbits are identified [67] in a process of data reconstruction from long-time observations of fussy star images. The Table 1 summarizes the unfolded orbital characteristics for several so-called S-stars: the semi-major axis a in meters, the eccentricity e, and the full time period in Earth's years.

Using the most directly observed parameters, we independently conducted the exact calculations of the orbits in the Classical, General Relativity, and SR Dynamics theories. The corresponding equations of motions, results, and discussions are presented below.

Equations of particle motion in Classical, GR, and SR Dynamics

GR and Classic Dynamics

In polar coordinates, the conventional Einstein's equation [68] of the test particle in the spherical symmetric gravitational field is given by

$$\left(\frac{\mathrm{d}x}{\mathrm{d}\theta}\right)^2 = \frac{(\epsilon_0^2 - 1)}{l_0^2} + \frac{2r_g}{l_0^2}x - x^2 + 2r_g x^3\,, \tag{30}$$

where $x = 1/r$ is the inverted radius, ϵ_0^2 and l_0^2 are the particle conserved total energy and angular momentum, correspondingly (both are in the squared form), $r_g = \mu/c^2$ the gravitational radius, $\mu = GM$. Mass of the particle m is assumed however small with respect to the point-like source mass M, $m \ll M$. Customary units $c = 1$, $m = 1$ are used. The dimensionless parameter of field strength is introduced $\rho_0 = r_g/r_0$, where r_0 is the initial radius. Then, (30) takes the dimensionless form

$$\left(\frac{\partial\xi}{\partial\theta}\right)^2 = \left(1 - \frac{2\rho_0}{\beta_0^2} - 2\rho_0\right) + \frac{2\rho_0}{\beta_0^2}\,\xi - \xi^2 + 2\rho_0\,\xi^3 \tag{31}$$

with the conserved total energy

$$\begin{aligned}\epsilon_0^2 &= 1 - 2\rho_0 + \beta_0^2 - 2\rho_0\beta_0^2\\ &= 1 - 2\rho_0\xi + \beta_0^2\xi^2 - 2\rho_0\beta_0^2\xi^3 + \beta_r^2(\xi)\,.\end{aligned} \tag{32}$$

The radial component of velocity is

$$\beta_r^2(\xi) = f^2(\xi) = \epsilon_0^2 - \left(1 - 2\rho_0\xi + \beta_0^2\xi^2 - 2\rho_0\beta_0^2\xi^3\right)\,. \tag{33}$$

The dimensionless parameter of initial angular (squared) velocity is $\beta_\theta^2 = \beta_0^2$. The equation of temporal motion comes from (33) with $r(\tau) = r_0/\xi$

$$\beta_r(\xi) = \frac{\mathrm{d}r(\tau)}{\mathrm{d}\tau} = f(r)\,, \tag{34}$$

where $f(r)$ is an explicit function of τ due to $\theta(\tau)$ and $r(\tau)$, (34).

Notice, the time variable in the equations is the proper time τ by virtue of derivation. We argue that it must be the coordinate time t.

The above equations are reduced to the Classical case if the term of the cubic order is neglected, and the time variable τ must be replaced with t.

The Alternative Relativistic Dynamics

We use a relativistic dynamics theory [34, 32] different from GR. In the referred works, the principles of relativistic dynamics are given and illustrated in the spherical symmetric field. The orbital motion problem is described in brief, as follows.

A new concept of the relativistic proper mass $m(r)$ depending on field strength is introduced. From the Lagrangian problem formulation, it follows $m(r) = m_0/\gamma_r$, where m_0 is the initial value, $m(r) \to m_\infty$ as $r \to \infty$.

The revision of the proper mass concept is motivated by several reasons, first of all, because of the elimination of the central singularity (the traditional infinity). Besides, it is a necessity to introduce the 4-momentum vector P^μ in the form complementary to the 4-coordinate vector X^μ. The temporal component in X^μ is the proper time depending on the gravitational potential $\tau = \tau(r_g/r)$. Therefore, the temporal component m in P^μ should be $m = m(r_g/r)$. This explains the gravitational time dilation.

In polar coordinates, the 4-coordinate interval and the 4-momentum vectors are $\mathrm{d}X^\mu(r) = \gamma\,\mathrm{d}\tau(r)\,(1, \beta_r, \beta_\theta)$ and $P^\mu(r) = \gamma\, m(r)\,(1, \beta_r, \beta_\theta)$, where 3-velocity components and the Lorentz factor are functions of r and θ, $c_0 = 1$. The Minkowski 4-force $K^\mu = \mathrm{d}P^\mu/\mathrm{d}\tau$ acts on the test particle, and it naturally has the tangential component with respect to the world-line s and the orthogonal one, while the a point on the world line s is a function of 4-position.

There are two conservation laws, – for total energy ϵ_0, and the angular momentum L_0 formulated below for initial conditions $r(r) = r_0$, $\theta = 0$, $\beta_r = 0$, $\beta_\theta = \beta_0$. The total energy and the angular momentum are

$$\epsilon_0 = \gamma_0\,\gamma_{r,0} = \gamma\,\gamma_r\,, \tag{35}$$

$$L_0 = \gamma_0\,\gamma_{r,0}\,r_0\,\beta_0 = \gamma\,\gamma_r\,r\,\beta_\theta\,. \tag{36}$$

Instead of (36), it is convenient to use a conserved quantity $l_0 = \epsilon_0/L_0$:

$$l_0 = r\,\beta_\theta\,. \tag{37}$$

The angular motion equation can be derived from the squared inverted Lorentz factor $1/\gamma^2 = 1 - \beta_r^2 - \beta_\theta^2$, and $\beta_r = \mathrm{d}r/\mathrm{d}t$, $\beta_\theta = r\,\mathrm{d}\theta/\mathrm{d}t$. Consider the expression $\beta_r = (\mathrm{d}r/\mathrm{d}\theta)(\mathrm{d}\theta/\mathrm{d}t)$ in relationship with $\beta_\theta^2 = l_0^2/r^2$ with a variable $\xi = r_0/r$. The equation is valid for a however strong field by the criterion r_g/r, compare with (31):

$$\left(\frac{\mathrm{d}\xi}{\mathrm{d}\theta}\right)^2 = \frac{1}{\beta_0^2} - \xi^2 - \frac{1}{\gamma_0^2\,\beta_0^2}\,\exp\left(\frac{2\,r_g}{r_0}\,(1-\xi)\right)\,. \tag{38}$$

The Newtonian limit, or weak field conditions, is given by a linear approximation of the exponential function:

$$(\mathrm{d}\xi/\mathrm{d}\theta)^2 = (1 - 2\,\sigma_r) + 2\,\sigma_r\,\xi - \xi^2 - 2\,\sigma_r\,(r_g/r_0)\,(1-\xi)^2\,, \tag{39}$$

where $\sigma_r = r_g/(r_0\,\gamma_0^2\,\beta_0^2)$ is the σ criterion in the relativistic case. It should be noted that

$$\mathrm{d}\xi/\mathrm{d}\theta = (\mathrm{d}r/\mathrm{d}t)/\beta_0\,, \tag{40}$$

where $(\mathrm{d}r/\mathrm{d}t)^2 = \beta_r^2(r)$ is the radial (squared) component to the total (squared) speed $\beta(r)$:

$$\beta^2(r) = \beta_r^2(r) + \beta_\theta^2\,, \tag{41}$$

with the angular speed term

$$\beta_\theta^2 = r_0^2\,\beta_0^2/r^2\,. \tag{42}$$

The potential function in the radial motion is

$$V(r) = -\left(1 - \exp(-r_g/r)\right)\,. \tag{43}$$

The particle speed a free radial fall is:

$$\beta(r) = \left(1 - (1/\gamma_0^2)\,\exp(-2\,r_g/r)\right)^{1/2}\,. \tag{44}$$

We applied all theories to compare the results of exact calculations of motion of stars in the central region of Milky Way.

A.4 Results of calculations

From the set of data in Table 1, it is seen that the evaluated orbits of the observed stars correspond to the motion under weak field conditions $r_0 \ll 1$, therefore, the expected differences in Classical, GR, and SR Dynamics theories will be small.

Let us fix the central mass and the eccentricity value and find the corresponding pericenter value together with all other orbital characteristics such as maximal velocity, semi-major axis, etc., to match the given time period within 0.001%. The results are presented in Table 2. As seen, the differences between the three theories are negligible.

From the GU Model viewpoint, the central mass should be initially much larger, say, $M_C = 2\times10^{39}$, as was discussed. Then, the stars would move 6-8 times faster and have correspondingly grater semi-major axis, see Table 3. At a pericenter, several stars would reach the speed about $\beta_0 \approx 0.1$, the star S14 reaching almost $\beta_0 \approx 0.2$, and the star S2 reaching $\beta_0 \approx 0.15$. Increasing the central mass up to $M_C = 1\times10^{40}$ will result in to $\beta_0 \approx 1/3$ for S14 and $\beta_0 \approx 2/7$ for S2, see Table 4. It is probable that, while the central mass was much larger before the collision, orbits of the stars were larger than observed, so that a motion of the stars could be characterized by a maximal speed not approaching the speed of light.

One of the stars closest to the galaxy center is the S2-star, which has been studied very thoroughly. Its orbital time full period is found to be about 16 years. Let us fix this period and the orbit eccentricity to reconstruct the orbit in each theory. The Classical Mechanics predicts faster velocities with increasing differences for larger central mass. In the SR Dynamics, a particle motion faster then light is impossible. However, Classical Theory gives, for central mass being over 4×10^{41} kg., the superluminal speed at pericenter, see Figure 1. General Relativity in this case predicts even faster velocities, moreover, for the central mass larger than 1.2×10^{41} kg the orbit type can be only either hyperbolic or a spiral fall. Recall, we deny the validity of the conventional GR gravitational field theory for the previously explained reasons.

For the values of the central mass larger than 1×10^{38} kg, there are noticeable differences in angular periods, see Figure 2. In GR theory the angular advance explodes very quick, while in exponential model the angular period shows some retardation.

The orbital characteristics calculated in the Classical, GR, and SR Dynamics models are provided by additional information in the following Tables to allow readers to interpolate the results to different combinations of initial conditions and illustrated graphically.

Table 1: Orbital data provided by [67, Table 7] with $M_C = 8.57 \times 10^{36}$ kg and $R_0 = 2.57 \times 10^{20}$ m. The last two entries are taken from more recent articles [69, Table 1] and [70, Table S4], where the central mass was estimated to be equal to $M_C = (4.1 \pm 0.4) \times 10^6 M_\odot \approx 8.15 \times 10^{36}$ kg and the distance $R_0 = 7.7 \pm 0.4$ kpc $\approx 2.38 \times 10^{20}$ m.

star	a (m)	e	T (years)
S1	6.330E+14	0.496	132.00
S2	1.533E+14	0.880	15.80
S4	3.714E+14	0.406	59.50
S5	3.115E+14	0.842	45.70
S6	5.433E+14	0.886	105.00
S8	5.122E+14	0.824	96.10
S9	3.651E+14	0.825	58.00
S12	3.838E+14	0.900	62.50
S13	3.701E+14	0.490	59.20
S14	3.190E+14	0.963	47.30
S17	3.876E+14	0.364	63.20
S18	3.302E+14	0.759	50.00
S19	9.944E+14	0.844	260.00
S21	2.654E+14	0.784	35.80
S24	1.321E+15	0.933	398.00
S27	5.658E+14	0.952	112.00
S29	4.947E+14	0.916	91.00
S31	3.714E+14	0.934	59.40
S33	5.109E+14	0.731	96.00
S38	1.732E+14	0.802	18.90
S66	1.508E+15	0.178	486.00
S67	1.365E+15	0.368	419.00
S71	1.322E+15	0.844	399.00
S83	3.471E+15	0.654	1700.00
S87	1.570E+15	0.423	516.00
S96	1.925E+15	0.131	701.00
S97	2.724E+15	0.302	1180.00
S2	1.417E+14	0.898	16.17
S102	1.219E+14	0.680	11.50

Table 2: Orbital parameters of S-stars for center mass $M_C = 8.57 \times 10^{36}$ kg, $r_g = 6.37 \times 10^9$ m, density = $7.93{\times}10^6$ kg/m^3 in exponential theory and relative differences to classical and GR theories. The last two entries are computed with $M_C = 8.15 \times 10^{36}$ kg, $r_g = 6.06 \times 10^9$ m, density = $8.77{\times}10^6$ kg/m^3 as in [69, 70].

	exp model			relative difference to CLT			relative difference to GRT		
star	a (m)	r_p (m)	v_p/c	a	r_p	v_p/c	a	r_p	v_p/c
S1	6.31E+14	3.18E+14	0.0055	-9E-06	-9E-06	1E-05	-2E-05	-2E-05	4E-05
S2	1.53E+14	1.84E+13	0.0255	-8E-06	-8E-06	2E-04	-5E-05	-5E-05	5E-04
S4	3.71E+14	2.20E+14	0.0064	-1E-05	-1E-05	2E-05	-3E-05	-3E-05	6E-05
S5	3.11E+14	4.91E+13	0.0154	-1E-05	-1E-05	7E-05	-3E-05	-3E-05	2E-04
S6	5.42E+14	6.17E+13	0.0139	0E+00	0E+00	5E-05	-1E-05	-1E-05	2E-04
S8	5.11E+14	8.99E+13	0.0114	-1E-05	-1E-05	4E-05	-2E-05	-2E-05	1E-04
S9	3.65E+14	6.38E+13	0.0135	-1E-05	-1E-05	5E-05	-3E-05	-3E-05	2E-04
S12	3.83E+14	3.83E+13	0.0178	0E+00	0E+00	8E-05	-2E-05	-2E-05	3E-04
S13	3.70E+14	1.89E+14	0.0071	0E+00	0E+00	1E-05	-2E-05	-2E-05	6E-05
S14	3.18E+14	1.18E+13	0.0326	-1E-05	-1E-05	3E-04	-3E-05	-3E-05	8E-04
S17	3.86E+14	2.46E+14	0.0059	-1E-05	-1E-05	2E-05	-3E-05	-3E-05	5E-05
S18	3.30E+14	7.96E+13	0.0119	0E+00	0E+00	4E-05	-2E-05	-2E-05	1E-04
S19	9.91E+14	1.55E+14	0.0087	0E+00	0E+00	2E-05	-9E-06	-9E-06	7E-05
S21	2.64E+14	5.71E+13	0.0141	0E+00	0E+00	5E-05	-3E-05	-3E-05	2E-04
S24	1.32E+15	8.82E+13	0.0118	0E+00	0E+00	3E-05	-1E-05	-1E-05	1E-04
S27	5.65E+14	2.71E+13	0.0214	0E+00	0E+00	1E-04	-1E-05	-1E-05	4E-04
S29	4.92E+14	4.14E+13	0.0172	0E+00	0E+00	7E-05	-1E-05	-1E-05	2E-04
S31	3.70E+14	2.45E+13	0.0224	-1E-05	-1E-05	1E-04	-2E-05	-2E-05	4E-04
S33	5.10E+14	1.37E+14	0.0090	-8E-06	-8E-06	2E-05	-1E-05	-1E-05	7E-05
S38	1.73E+14	3.42E+13	0.0183	-2E-05	-2E-05	9E-05	-6E-05	-6E-05	3E-04
S66	1.50E+15	1.24E+15	0.0025	0E+00	0E+00	2E-06	-1E-06	-1E-06	1E-05
S67	1.36E+15	8.61E+14	0.0032	-1E-05	-1E-05	9E-06	-8E-06	-8E-06	2E-05
S71	1.32E+15	2.06E+14	0.0076	0E+00	0E+00	1E-05	5E-06	5E-06	4E-05
S83	3.47E+15	1.20E+15	0.0030	0E+00	0E+00	2E-06	-5E-06	-5E-06	1E-05
S87	1.57E+15	9.03E+14	0.0032	0E+00	0E+00	3E-06	-3E-06	-3E-06	1E-05
S96	1.92E+15	1.67E+15	0.0021	0E+00	0E+00	2E-06	-3E-06	-3E-06	8E-06
S97	2.72E+15	1.90E+15	0.0021	0E+00	0E+00	1E-06	-6E-06	-6E-06	8E-06
S2	1.53E+14	1.56E+13	0.0271	-7E-06	-7E-06	2E-04	-5E-05	-5E-05	6E-04
S102	1.22E+14	3.90E+13	0.0161	-2E-05	-2E-05	8E-05	-7E-05	-7E-05	3E-04

Table 3: Orbital parameters of S-stars for center mass $M_C = 2 \times 10^{39}$ kg, $r_g = 1.49 \times 10^{12}$ m, density = 146 kg/m^3 in exponential theory and relative differences to classical and GR theories.

	exp model			relative difference to CLT			relative difference to GRT		
star	a (m)	r_p (m)	v_p/c	a	r_p	v_p/c	a	r_p	v_p/c
S1	3.88E+15	1.96E+15	0.0337	-1E-04	-1E-04	4E-04	-5E-04	-5E-04	1E-03
S2	9.44E+14	1.13E+14	0.1560	-5E-04	-5E-04	6E-03	-2E-03	-2E-03	2E-02
S4	2.28E+15	1.36E+15	0.0392	-2E-04	-2E-04	6E-04	-9E-04	-9E-04	2E-03
S5	1.92E+15	3.03E+14	0.0949	-3E-04	-3E-04	2E-03	-1E-03	-1E-03	8E-03
S6	3.33E+15	3.80E+14	0.0857	-1E-04	-1E-04	2E-03	-6E-04	-6E-04	6E-03
S8	3.14E+15	5.53E+14	0.0699	-2E-04	-2E-04	1E-03	-6E-04	-6E-04	4E-03
S9	2.25E+15	3.93E+14	0.0829	-2E-04	-2E-04	2E-03	-9E-04	-9E-04	6E-03
S12	2.36E+15	2.36E+14	0.1090	-2E-04	-2E-04	3E-03	-8E-04	-8E-04	1E-02
S13	2.28E+15	1.16E+15	0.0436	-2E-04	-2E-04	6E-04	-9E-04	-9E-04	2E-03
S14	1.96E+15	7.25E+13	0.1985	-2E-04	-2E-04	1E-02	-1E-03	-1E-03	3E-02
S17	2.38E+15	1.51E+15	0.0366	-2E-04	-2E-04	5E-04	-8E-04	-8E-04	2E-03
S18	2.03E+15	4.90E+14	0.0729	-2E-04	-2E-04	1E-03	-1E-03	-1E-03	5E-03
S19	6.10E+15	9.52E+14	0.0536	-9E-05	-9E-05	8E-04	-3E-04	-3E-04	2E-03
S21	1.63E+15	3.52E+14	0.0866	-3E-04	-3E-04	2E-03	-1E-03	-1E-03	7E-03
S24	8.11E+15	5.43E+14	0.0726	-7E-05	-7E-05	1E-03	-2E-04	-2E-04	4E-03
S27	3.48E+15	1.67E+14	0.1311	-1E-04	-1E-04	4E-03	-6E-04	-6E-04	1E-02
S29	3.03E+15	2.55E+14	0.1054	-2E-04	-2E-04	3E-03	-7E-04	-7E-04	9E-03
S31	2.28E+15	1.51E+14	0.1375	-2E-04	-2E-04	5E-03	-9E-04	-9E-04	2E-02
S33	3.14E+15	8.45E+14	0.0551	-2E-04	-2E-04	9E-04	-6E-04	-6E-04	3E-03
S38	1.06E+15	2.11E+14	0.1124	-5E-04	-5E-04	3E-03	-2E-03	-2E-03	1E-02
S66	9.26E+15	7.61E+15	0.0152	-6E-05	-6E-05	1E-04	-2E-04	-2E-04	4E-04
S67	8.39E+15	5.30E+15	0.0196	-5E-05	-5E-05	1E-04	-2E-04	-2E-04	6E-04
S71	8.12E+15	1.27E+15	0.0465	-6E-05	-6E-05	6E-04	-3E-04	-3E-04	2E-03
S83	2.13E+16	7.38E+15	0.0182	-3E-05	-3E-05	1E-04	-1E-04	-1E-04	3E-04
S87	9.64E+15	5.56E+15	0.0195	-5E-05	-5E-05	1E-04	-2E-04	-2E-04	5E-04
S96	1.18E+16	1.03E+16	0.0128	-4E-05	-4E-05	8E-05	-2E-04	-2E-04	3E-04
S97	1.67E+16	1.17E+16	0.0129	-2E-05	-2E-05	6E-05	-1E-04	-1E-04	3E-04
S2	9.58E+14	9.78E+13	0.1686	-5E-04	-5E-04	7E-03	-2E-03	-2E-03	2E-02
S102	7.64E+14	2.44E+14	0.1008	-6E-04	-6E-04	3E-03	-3E-03	-3E-03	1E-02

Table 4: Orbital parameters of S-stars for center mass $M_C = 1 \times 10^{40}$ kg, $r_g = 7.43 \times 10^{12}$ m, density = 5.83 kg/m^3 in exponential theory and relative differences to classical and GR theories.

	exp model			relative difference to CLT			relative difference to GRT		
star	a (m)	r_p (m)	v_p/c	a	r_p	v_p/c	a	r_p	v_p/c
S1	6.64E+15	3.35E+15	0.0575	-4E-04	-4E-04	1E-03	-2E-03	-2E-03	4E-03
S2	1.62E+15	1.94E+14	0.2636	-1E-03	-1E-03	2E-02	-7E-03	-7E-03	6E-02
S4	3.91E+15	2.32E+15	0.0670	-6E-04	-6E-04	2E-03	-3E-03	-3E-03	6E-03
S5	3.28E+15	5.18E+14	0.1615	-7E-04	-7E-04	7E-03	-3E-03	-3E-03	2E-02
S6	5.70E+15	6.50E+14	0.1460	-4E-04	-4E-04	6E-03	-2E-03	-2E-03	2E-02
S8	5.38E+15	9.46E+14	0.1192	-5E-04	-5E-04	4E-03	-2E-03	-2E-03	1E-02
S9	3.84E+15	6.72E+14	0.1413	-6E-04	-6E-04	5E-03	-3E-03	-3E-03	2E-02
S12	4.04E+15	4.04E+14	0.1853	-6E-04	-6E-04	9E-03	-3E-03	-3E-03	3E-02
S13	3.89E+15	1.99E+15	0.0745	-6E-04	-6E-04	2E-03	-3E-03	-3E-03	7E-03
S14	3.35E+15	1.24E+14	0.3330	-7E-04	-7E-04	3E-02	-3E-03	-3E-03	1E-01
S17	4.07E+15	2.59E+15	0.0625	-6E-04	-6E-04	1E-03	-2E-03	-2E-03	6E-03
S18	3.48E+15	8.39E+14	0.1243	-7E-04	-7E-04	4E-03	-3E-03	-3E-03	1E-02
S19	1.04E+16	1.63E+15	0.0915	-2E-04	-2E-04	2E-03	-1E-03	-1E-03	7E-03
S21	2.79E+15	6.02E+14	0.1476	-9E-04	-9E-04	6E-03	-4E-03	-4E-03	2E-02
S24	1.39E+16	9.29E+14	0.1238	-2E-04	-2E-04	4E-03	-7E-04	-7E-04	1E-02
S27	5.95E+15	2.86E+14	0.2224	-4E-04	-4E-04	1E-02	-2E-03	-2E-03	4E-02
S29	5.19E+15	4.36E+14	0.1793	-5E-04	-5E-04	8E-03	-2E-03	-2E-03	3E-02
S31	3.90E+15	2.58E+14	0.2329	-6E-04	-6E-04	1E-02	-3E-03	-3E-03	5E-02
S33	5.37E+15	1.45E+15	0.0941	-5E-04	-5E-04	3E-03	-2E-03	-2E-03	9E-03
S38	1.82E+15	3.60E+14	0.1909	-1E-03	-1E-03	1E-02	-6E-03	-6E-03	3E-02
S66	1.58E+16	1.30E+16	0.0259	-2E-04	-2E-04	3E-04	-6E-04	-6E-04	1E-03
S67	1.43E+16	9.07E+15	0.0335	-2E-04	-2E-04	4E-04	-7E-04	-7E-04	2E-03
S71	1.39E+16	2.17E+15	0.0794	-2E-04	-2E-04	2E-03	-7E-04	-7E-04	5E-03
S83	3.65E+16	1.26E+16	0.0312	-7E-05	-7E-05	3E-04	-3E-04	-3E-04	1E-03
S87	1.65E+16	9.51E+15	0.0333	-2E-04	-2E-04	4E-04	-6E-04	-6E-04	2E-03
S96	2.02E+16	1.76E+16	0.0219	-1E-04	-1E-04	2E-04	-5E-04	-5E-04	1E-03
S97	2.86E+16	2.00E+16	0.0220	-9E-05	-9E-05	2E-04	-3E-04	-3E-04	8E-04
S2	1.64E+15	1.67E+14	0.2842	-1E-03	-1E-03	2E-02	-6E-03	-6E-03	7E-02
S102	1.31E+15	4.18E+14	0.1713	-2E-03	-2E-03	9E-03	-8E-03	-8E-03	3E-02

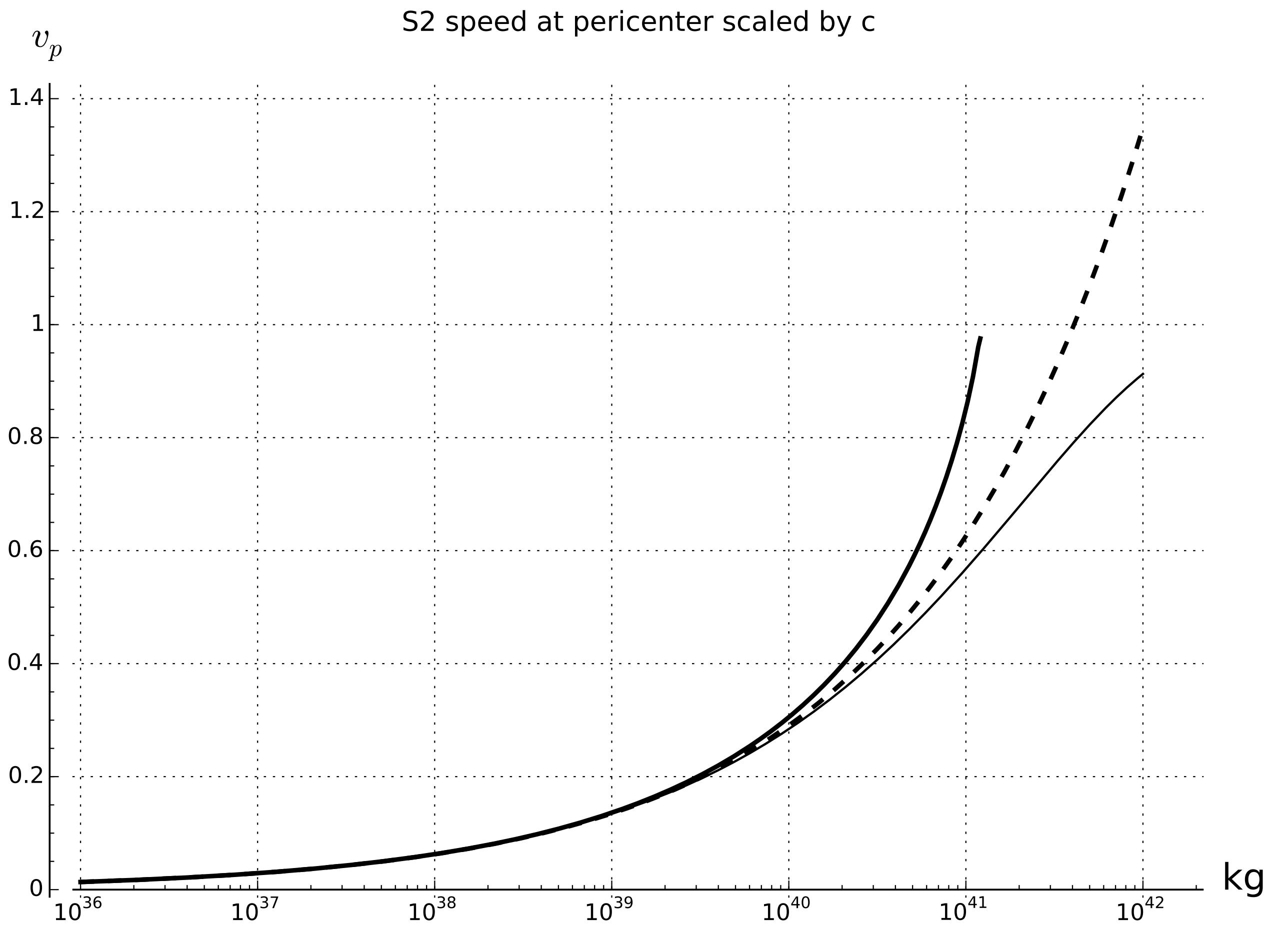

Figure 1: S2 speed at pericenter depending on the value of the central mass: dashed line for the Classical Theory, top solid line for GR, bottom line for our model.

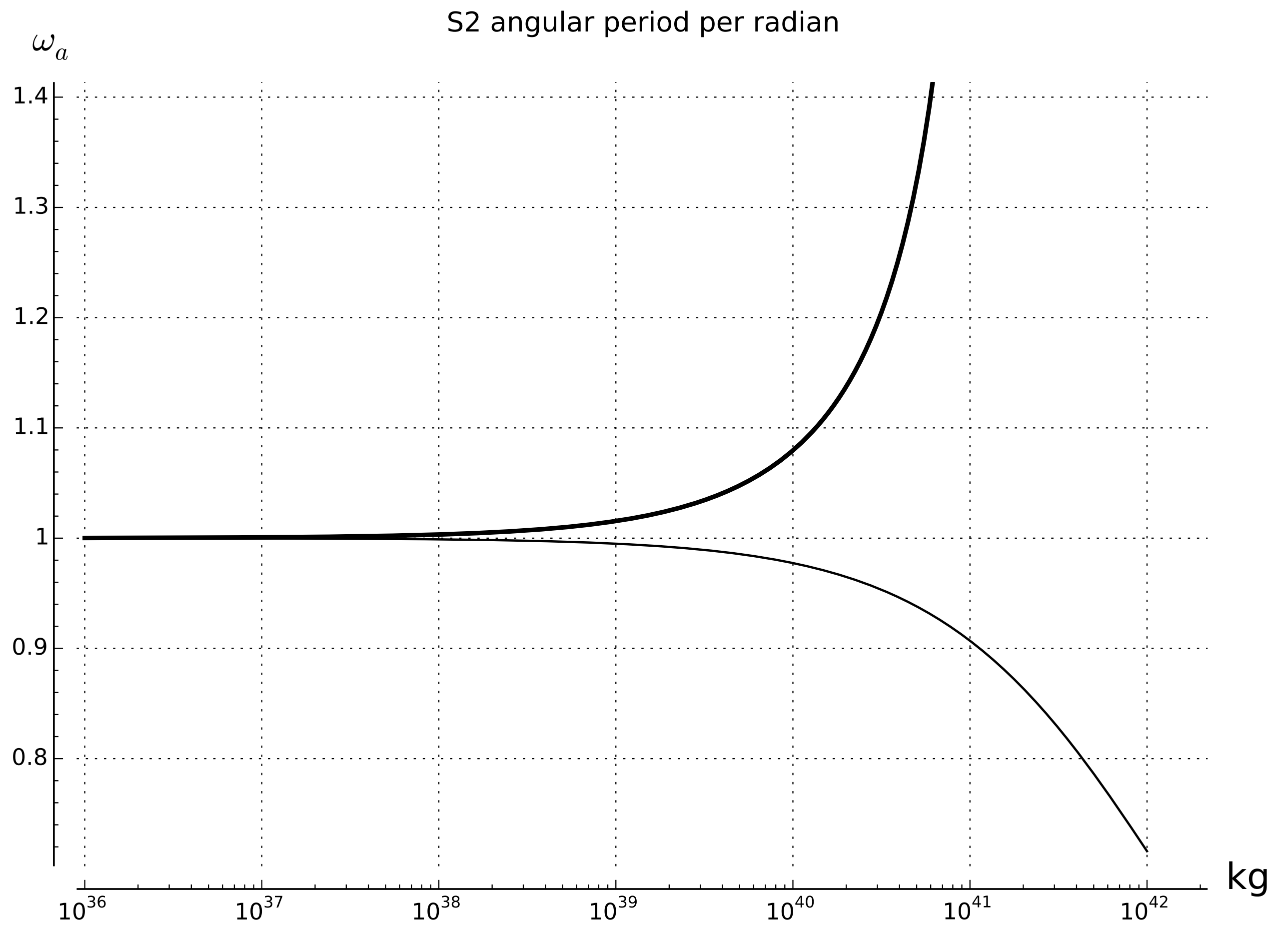

Figure 2: S2 angular period per radian: in Classical Theory it is constant 1, the top thick solid line corresponds to GR theory, thiner bottom line corresponds to our model.

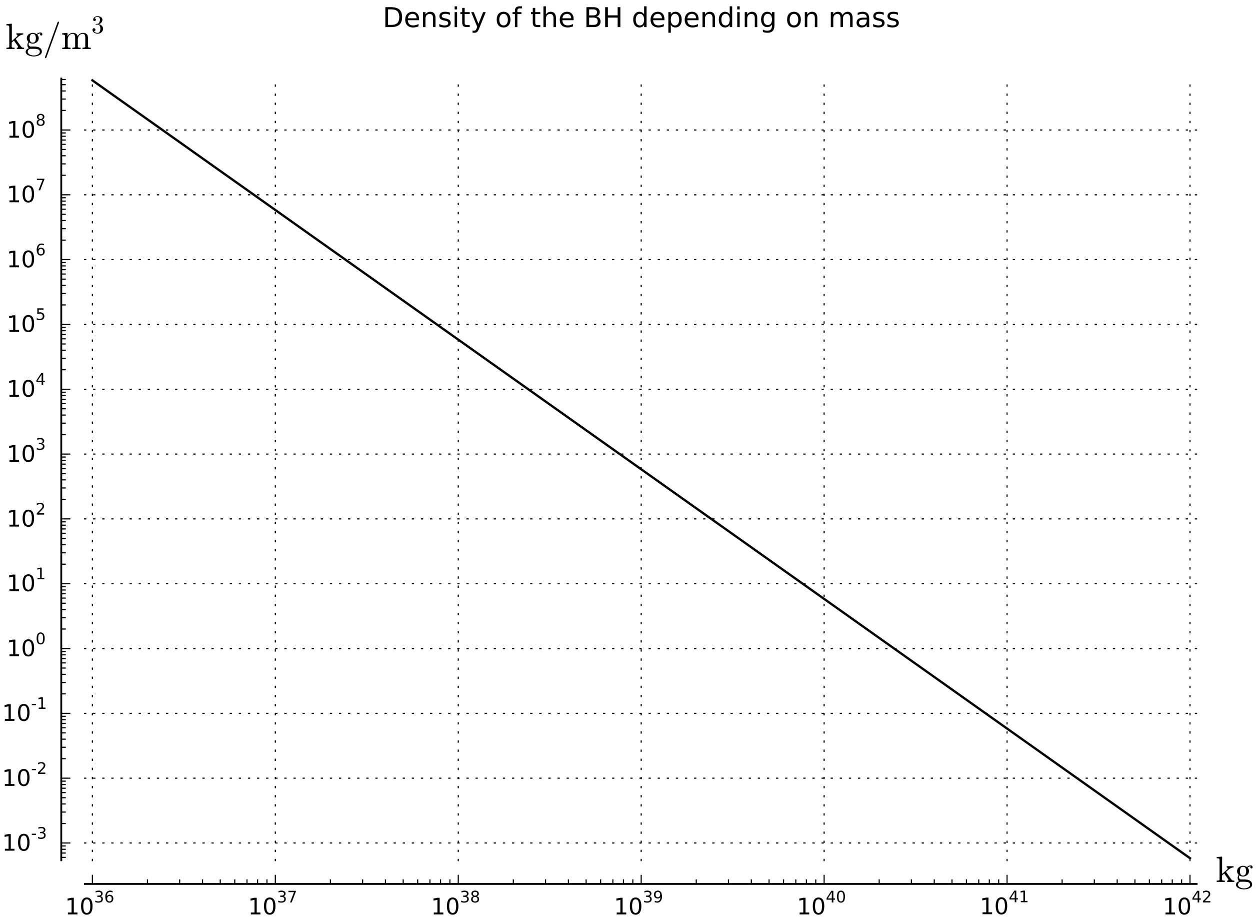

Figure 3: Central mass density

Table 5: Exponential model for $M_C = 8.57 \times 10^{36}$ kg, $r_g = 6.37 \times 10^9$ m, density $= 7.93 \times 10^6$ kg/m^3. The two last entries computed for $M_C = 8.15 \times 10^{36}$ kg, $r_g = 6.06 \times 10^9$ m, density $= 8.77 \times 10^6$ kg/m^3.

star	r_p (m)	r_a (m)	ω_a/π	ρ_0	β_0^2	σ_0
S1	3.180E+14	9.438E+14	0.9999866	2.002E-05	2.995E-05	0.668
S2	1.839E+13	2.881E+14	0.9998159	3.462E-04	6.506E-04	0.532
S4	2.203E+14	5.215E+14	0.9999795	2.889E-05	4.062E-05	0.711
S5	4.915E+13	5.730E+14	0.9999297	1.295E-04	2.385E-04	0.543
S6	6.175E+13	1.022E+15	0.9999453	1.031E-04	1.944E-04	0.530
S8	8.986E+13	9.313E+14	0.9999612	7.084E-05	1.292E-04	0.548
S9	6.381E+13	6.655E+14	0.9999453	9.975E-05	1.820E-04	0.548
S12	3.833E+13	7.282E+14	0.9999126	1.661E-04	3.155E-04	0.526
S13	1.885E+14	5.508E+14	0.9999773	3.377E-05	5.031E-05	0.671
S14	1.178E+13	6.248E+14	0.9997248	5.405E-04	1.060E-03	0.510
S17	2.456E+14	5.267E+14	0.9999810	2.592E-05	3.536E-05	0.733
S18	7.960E+13	5.810E+14	0.9999545	7.997E-05	1.407E-04	0.569
S19	1.547E+14	1.828E+15	0.9999777	4.116E-05	7.590E-05	0.542
S21	5.710E+13	4.716E+14	0.9999375	1.115E-04	1.989E-04	0.561
S24	8.822E+13	2.545E+15	0.9999627	7.215E-05	1.395E-04	0.517
S27	2.714E+13	1.104E+15	0.9998799	2.345E-04	4.577E-04	0.512
S29	4.136E+13	9.433E+14	0.9999197	1.539E-04	2.949E-04	0.522
S31	2.445E+13	7.165E+14	0.9998654	2.603E-04	5.034E-04	0.517
S33	1.373E+14	8.832E+14	0.9999732	4.638E-05	8.028E-05	0.578
S38	3.419E+13	3.112E+14	0.9998967	1.862E-04	3.355E-04	0.555
S66	1.237E+15	1.772E+15	0.9999956	5.148E-06	6.064E-06	0.849
S67	8.612E+14	1.864E+15	0.9999946	7.391E-06	1.011E-05	0.731
S71	2.058E+14	2.432E+15	0.9999832	3.094E-05	5.705E-05	0.542
S83	1.199E+15	5.733E+15	0.9999968	5.307E-06	8.778E-06	0.605
S87	9.033E+14	2.228E+15	0.9999950	7.047E-06	1.003E-05	0.703
S96	1.669E+15	2.172E+15	0.9999966	3.814E-06	4.314E-06	0.884
S97	1.897E+15	3.538E+15	0.9999974	3.356E-06	4.369E-06	0.768
S2	1.561E+13	2.905E+14	0.9997957	3.879E-04	7.360E-04	0.527
S102	3.902E+13	2.049E+14	0.9999076	1.552E-04	2.607E-04	0.595

Table 6: Classical theory for $M_C = 8.57 \times 10^{36}$ kg, $r_g = 6.37 \times 10^9$ m, density = 7.93×10^6 kg/m^3. The two last entries computed for $M_C = 8.15 \times 10^{36}$ kg, $r_g = 6.06 \times 10^9$ m, density = 8.77×10^6 kg/m^3.

star	r_p (m)	r_a (m)	ω_a/π	ρ_0	β_0^2	σ_0
S1	3.180E+14	9.438E+14	1	2.002E-05	2.995E-05	0.668
S2	1.839E+13	2.881E+14	1	3.462E-04	6.508E-04	0.532
S4	2.203E+14	5.215E+14	1	2.889E-05	4.062E-05	0.711
S5	4.915E+13	5.730E+14	1	1.295E-04	2.386E-04	0.543
S6	6.175E+13	1.022E+15	1	1.031E-04	1.944E-04	0.530
S8	8.986E+13	9.313E+14	1	7.084E-05	1.292E-04	0.548
S9	6.381E+13	6.655E+14	1	9.976E-05	1.821E-04	0.548
S12	3.833E+13	7.282E+14	1	1.661E-04	3.156E-04	0.526
S13	1.885E+14	5.508E+14	1	3.377E-05	5.031E-05	0.671
S14	1.178E+13	6.248E+14	1	5.405E-04	1.061E-03	0.509
S17	2.456E+14	5.267E+14	1	2.592E-05	3.536E-05	0.733
S18	7.960E+13	5.810E+14	1	7.997E-05	1.407E-04	0.569
S19	1.547E+14	1.828E+15	1	4.116E-05	7.590E-05	0.542
S21	5.710E+13	4.716E+14	1	1.115E-04	1.989E-04	0.561
S24	8.822E+13	2.545E+15	1	7.215E-05	1.395E-04	0.517
S27	2.714E+13	1.104E+15	1	2.345E-04	4.578E-04	0.512
S29	4.136E+13	9.433E+14	1	1.539E-04	2.949E-04	0.522
S31	2.445E+13	7.165E+14	1	2.603E-04	5.035E-04	0.517
S33	1.372E+14	8.832E+14	1	4.638E-05	8.028E-05	0.578
S38	3.419E+13	3.112E+14	1	1.862E-04	3.355E-04	0.555
S66	1.237E+15	1.772E+15	1	5.148E-06	6.064E-06	0.849
S67	8.612E+14	1.864E+15	1	7.392E-06	1.011E-05	0.731
S71	2.058E+14	2.432E+15	1	3.094E-05	5.705E-05	0.542
S83	1.199E+15	5.733E+15	1	5.307E-06	8.779E-06	0.605
S87	9.033E+14	2.228E+15	1	7.047E-06	1.003E-05	0.703
S96	1.669E+15	2.172E+15	1	3.814E-06	4.314E-06	0.884
S97	1.897E+15	3.538E+15	1	3.356E-06	4.369E-06	0.768
S2	1.561E+13	2.905E+14	1	3.879E-04	7.362E-04	0.527
S102	3.902E+13	2.049E+14	1	1.552E-04	2.607E-04	0.595

Table 7: GR theory for $M_C = 8.57\times10^{36}$ kg, $r_g = 6.37\times10^9$ m, density $= 7.93\times10^6$ kg/m^3. The two last entries computed for $M_C = 8.15\times10^{36}$ kg, $r_g = 6.06\times10^9$ m, density $= 8.77\times10^6$ kg/m^3.

star	r_p (m)	r_a (m)	ω_a/π	ρ_0	β_0^2	σ_0
S1	1.958E+15	5.811E+15	0.9994933	7.586E-04	1.134E-03	0.669
S2	1.133E+14	1.774E+15	0.9930971	1.311E-02	2.435E-02	0.539
S4	1.357E+15	3.211E+15	0.9992223	1.095E-03	1.538E-03	0.712
S5	3.026E+14	3.528E+15	0.9973465	4.907E-03	8.998E-03	0.545
S6	3.802E+14	6.290E+15	0.9979351	3.907E-03	7.341E-03	0.532
S8	5.533E+14	5.734E+15	0.9985316	2.684E-03	4.884E-03	0.550
S9	3.929E+14	4.098E+15	0.9979353	3.780E-03	6.874E-03	0.550
S12	2.360E+14	4.484E+15	0.9967041	6.293E-03	1.189E-02	0.529
S13	1.161E+15	3.391E+15	0.9991424	1.279E-03	1.904E-03	0.672
S14	7.252E+13	3.847E+15	0.9897275	2.048E-02	3.941E-02	0.520
S17	1.512E+15	3.243E+15	0.9992807	9.822E-04	1.339E-03	0.734
S18	4.901E+14	3.577E+15	0.9982818	3.030E-03	5.315E-03	0.570
S19	9.521E+14	1.125E+16	0.9991552	1.560E-03	2.872E-03	0.543
S21	3.516E+14	2.904E+15	0.9976407	4.224E-03	7.507E-03	0.563
S24	5.431E+14	1.567E+16	0.9985884	2.734E-03	5.272E-03	0.519
S27	1.671E+14	6.796E+15	0.9954779	8.887E-03	1.720E-02	0.517
S29	2.546E+14	5.808E+15	0.9969698	5.832E-03	1.111E-02	0.525
S31	1.506E+14	4.412E+15	0.9949383	9.864E-03	1.890E-02	0.522
S33	8.451E+14	5.438E+15	0.9989863	1.757E-03	3.037E-03	0.579
S38	2.106E+14	1.916E+15	0.9961088	7.053E-03	1.263E-02	0.559
S66	7.613E+15	1.091E+16	0.9998344	1.951E-04	2.298E-04	0.849
S67	5.302E+15	1.148E+16	0.9997953	2.801E-04	3.831E-04	0.731
S71	1.267E+15	1.497E+16	0.9993648	1.172E-03	2.160E-03	0.543
S83	7.384E+15	3.530E+16	0.9998784	2.011E-04	3.326E-04	0.605
S87	5.561E+15	1.372E+16	0.9998124	2.670E-04	3.799E-04	0.703
S96	1.027E+16	1.337E+16	0.9998722	1.446E-04	1.635E-04	0.884
S97	1.168E+16	2.178E+16	0.9999023	1.272E-04	1.656E-04	0.768
S2	9.777E+13	1.819E+15	0.9920911	1.519E-02	2.842E-02	0.535
S102	2.444E+14	1.283E+15	0.9964025	6.077E-03	1.015E-02	0.598

Table 8: Exponential model for $M_C = 2 \times 10^{39}$ kg, $r_g = 1.49 \times 10^{12}$ m, density = 146 kg/m^3.

star	r_p (m)	r_a (m)	ω_a/π	ρ_0	β_0^2	σ_0
S1	1.958E+15	5.811E+15	0.9994933	7.586E-04	1.134E-03	0.669
S2	1.133E+14	1.774E+15	0.9930971	1.311E-02	2.435E-02	0.539
S4	1.357E+15	3.211E+15	0.9992223	1.095E-03	1.538E-03	0.712
S5	3.026E+14	3.528E+15	0.9973465	4.907E-03	8.998E-03	0.545
S6	3.802E+14	6.290E+15	0.9979351	3.907E-03	7.341E-03	0.532
S8	5.533E+14	5.734E+15	0.9985316	2.684E-03	4.884E-03	0.550
S9	3.929E+14	4.098E+15	0.9979353	3.780E-03	6.874E-03	0.550
S12	2.360E+14	4.484E+15	0.9967041	6.293E-03	1.189E-02	0.529
S13	1.161E+15	3.391E+15	0.9991424	1.279E-03	1.904E-03	0.672
S14	7.252E+13	3.847E+15	0.9897275	2.048E-02	3.941E-02	0.520
S17	1.512E+15	3.243E+15	0.9992807	9.822E-04	1.339E-03	0.734
S18	4.901E+14	3.577E+15	0.9982818	3.030E-03	5.315E-03	0.570
S19	9.521E+14	1.125E+16	0.9991552	1.560E-03	2.872E-03	0.543
S21	3.516E+14	2.904E+15	0.9976407	4.224E-03	7.507E-03	0.563
S24	5.431E+14	1.567E+16	0.9985884	2.734E-03	5.272E-03	0.519
S27	1.671E+14	6.796E+15	0.9954779	8.887E-03	1.720E-02	0.517
S29	2.546E+14	5.808E+15	0.9969698	5.832E-03	1.111E-02	0.525
S31	1.506E+14	4.412E+15	0.9949383	9.864E-03	1.890E-02	0.522
S33	8.451E+14	5.438E+15	0.9989863	1.757E-03	3.037E-03	0.579
S38	2.106E+14	1.916E+15	0.9961088	7.053E-03	1.263E-02	0.559
S66	7.613E+15	1.091E+16	0.9998344	1.951E-04	2.298E-04	0.849
S67	5.302E+15	1.148E+16	0.9997953	2.801E-04	3.831E-04	0.731
S71	1.267E+15	1.497E+16	0.9993648	1.172E-03	2.160E-03	0.543
S83	7.384E+15	3.530E+16	0.9998784	2.011E-04	3.326E-04	0.605
S87	5.561E+15	1.372E+16	0.9998124	2.670E-04	3.799E-04	0.703
S96	1.027E+16	1.337E+16	0.9998722	1.446E-04	1.635E-04	0.884
S97	1.168E+16	2.178E+16	0.9999023	1.272E-04	1.656E-04	0.768
S2	9.777E+13	1.819E+15	0.9920911	1.519E-02	2.842E-02	0.535
S102	2.444E+14	1.283E+15	0.9964025	6.077E-03	1.015E-02	0.598

Table 9: Classical theory for $M_C = 2 \times 10^{39}$ kg, $r_g = 1.49 \times 10^{12}$ m, density = 146 kg/m^3.

star	r_p (m)	r_a (m)	ω_a/π	ρ_0	β_0^2	σ_0
S1	1.957E+15	5.810E+15	1	7.587E-04	1.135E-03	0.668
S2	1.132E+14	1.773E+15	1	1.312E-02	2.467E-02	0.532
S4	1.356E+15	3.210E+15	1	1.095E-03	1.540E-03	0.711
S5	3.026E+14	3.527E+15	1	4.909E-03	9.042E-03	0.543
S6	3.801E+14	6.289E+15	1	3.907E-03	7.369E-03	0.530
S8	5.532E+14	5.733E+15	1	2.685E-03	4.897E-03	0.548
S9	3.928E+14	4.097E+15	1	3.781E-03	6.900E-03	0.548
S12	2.359E+14	4.483E+15	1	6.295E-03	1.196E-02	0.526
S13	1.161E+15	3.391E+15	1	1.280E-03	1.907E-03	0.671
S14	7.250E+13	3.846E+15	1	2.049E-02	4.021E-02	0.509
S17	1.512E+15	3.242E+15	1	9.824E-04	1.340E-03	0.733
S18	4.900E+14	3.577E+15	1	3.031E-03	5.331E-03	0.569
S19	9.521E+14	1.125E+16	1	1.560E-03	2.877E-03	0.542
S21	3.515E+14	2.903E+15	1	4.225E-03	7.538E-03	0.561
S24	5.431E+14	1.567E+16	1	2.735E-03	5.286E-03	0.517
S27	1.671E+14	6.795E+15	1	8.889E-03	1.735E-02	0.512
S29	2.546E+14	5.807E+15	1	5.833E-03	1.118E-02	0.522
S31	1.505E+14	4.411E+15	1	9.866E-03	1.908E-02	0.517
S33	8.449E+14	5.437E+15	1	1.758E-03	3.043E-03	0.578
S38	2.105E+14	1.916E+15	1	7.056E-03	1.272E-02	0.555
S66	7.612E+15	1.091E+16	1	1.951E-04	2.298E-04	0.849
S67	5.302E+15	1.148E+16	1	2.801E-04	3.832E-04	0.731
S71	1.267E+15	1.497E+16	1	1.172E-03	2.162E-03	0.542
S83	7.384E+15	3.530E+16	1	2.011E-04	3.327E-04	0.605
S87	5.561E+15	1.371E+16	1	2.671E-04	3.800E-04	0.703
S96	1.027E+16	1.337E+16	1	1.446E-04	1.635E-04	0.884
S97	1.168E+16	2.178E+16	1	1.272E-04	1.656E-04	0.768
S2	9.772E+13	1.818E+15	1	1.520E-02	2.885E-02	0.527
S102	2.443E+14	1.282E+15	1	6.080E-03	1.022E-02	0.595

Table 10: GR theory for $M_C = 2 \times 10^{39}$ kg, $r_g = 1.49 \times 10^{12}$ m, density = 146 kg/m^3.

star	r_p (m)	r_a (m)	ω_a/π	ρ_0	β_0^2	σ_0
S1	1.957E+15	5.808E+15	1.0015256	7.590E-04	1.137E-03	0.667
S2	1.130E+14	1.771E+15	1.0216852	1.314E-02	2.538E-02	0.518
S4	1.355E+15	3.208E+15	1.0023463	1.096E-03	1.544E-03	0.709
S5	3.023E+14	3.525E+15	1.0081019	4.912E-03	9.139E-03	0.538
S6	3.800E+14	6.286E+15	1.0062789	3.909E-03	7.430E-03	0.526
S8	5.529E+14	5.730E+15	1.0044483	2.686E-03	4.926E-03	0.545
S9	3.926E+14	4.094E+15	1.0062797	3.783E-03	6.957E-03	0.544
S12	2.358E+14	4.480E+15	1.0101030	6.299E-03	1.212E-02	0.520
S13	1.160E+15	3.389E+15	1.0025884	1.281E-03	1.913E-03	0.669
S14	7.244E+13	3.843E+15	1.0329750	2.050E-02	4.197E-02	0.489
S17	1.511E+15	3.240E+15	1.0021691	9.830E-04	1.344E-03	0.731
S18	4.897E+14	3.574E+15	1.0052147	3.033E-03	5.368E-03	0.565
S19	9.518E+14	1.125E+16	1.0025486	1.560E-03	2.886E-03	0.541
S21	3.512E+14	2.900E+15	1.0071911	4.229E-03	7.610E-03	0.556
S24	5.430E+14	1.567E+16	1.0042733	2.735E-03	5.316E-03	0.514
S27	1.670E+14	6.792E+15	1.0139685	8.892E-03	1.767E-02	0.503
S29	2.545E+14	5.804E+15	1.0092714	5.836E-03	1.131E-02	0.516
S31	1.504E+14	4.408E+15	1.0156941	9.873E-03	1.948E-02	0.507
S33	8.445E+14	5.435E+15	1.0030622	1.759E-03	3.055E-03	0.576
S38	2.102E+14	1.913E+15	1.0119838	7.066E-03	1.292E-02	0.547
S66	7.611E+15	1.091E+16	1.0004973	1.951E-04	2.300E-04	0.848
S67	5.301E+15	1.147E+16	1.0006150	2.802E-04	3.835E-04	0.731
S71	1.266E+15	1.497E+16	1.0019136	1.173E-03	2.168E-03	0.541
S83	7.383E+15	3.529E+16	1.0003651	2.012E-04	3.329E-04	0.604
S87	5.560E+15	1.371E+16	1.0005636	2.671E-04	3.803E-04	0.702
S96	1.027E+16	1.337E+16	1.0003837	1.446E-04	1.636E-04	0.884
S97	1.168E+16	2.178E+16	1.0002932	1.272E-04	1.657E-04	0.768
S2	9.756E+13	1.815E+15	1.0250110	1.522E-02	2.980E-02	0.511
S102	2.438E+14	1.280E+15	1.0110652	6.093E-03	1.037E-02	0.588

Table 11: Exponential model for $M_C = 1 \times 10^{40}$ kg, $r_g = 7.43 \times 10^{12}$ m, density = 5.83 kg/m^3.

star	r_p (m)	r_a (m)	ω_a/π	ρ_0	β_0^2	σ_0
S1	3.349E+15	9.939E+15	0.9985209	2.218E-03	3.311E-03	0.670
S2	1.939E+14	3.037E+15	0.9802277	3.831E-02	6.947E-02	0.551
S4	2.321E+15	5.493E+15	0.9977319	3.200E-03	4.487E-03	0.713
S5	5.178E+14	6.036E+15	0.9923037	1.434E-02	2.607E-02	0.550
S6	6.503E+14	1.076E+16	0.9939996	1.142E-02	2.131E-02	0.536
S8	9.464E+14	9.808E+15	0.9957258	7.846E-03	1.421E-02	0.552
S9	6.722E+14	7.010E+15	0.9940010	1.105E-02	1.996E-02	0.554
S12	4.037E+14	7.670E+15	0.9904573	1.839E-02	3.434E-02	0.536
S13	1.986E+15	5.802E+15	0.9974997	3.739E-03	5.554E-03	0.673
S14	1.241E+14	6.582E+15	0.9708387	5.986E-02	1.109E-01	0.540
S17	2.587E+15	5.548E+15	0.9979019	2.871E-03	3.906E-03	0.735
S18	8.385E+14	6.120E+15	0.9950032	8.856E-03	1.545E-02	0.573
S19	1.628E+15	1.925E+16	0.9975361	4.560E-03	8.374E-03	0.545
S21	6.016E+14	4.969E+15	0.9931520	1.234E-02	2.178E-02	0.567
S24	9.289E+14	2.680E+16	0.9958897	7.995E-03	1.533E-02	0.521
S27	2.858E+14	1.162E+16	0.9869509	2.598E-02	4.945E-02	0.525
S29	4.356E+14	9.935E+15	0.9912192	1.705E-02	3.214E-02	0.531
S31	2.576E+14	7.547E+15	0.9854182	2.883E-02	5.423E-02	0.532
S33	1.445E+15	9.302E+15	0.9970454	5.137E-03	8.852E-03	0.580
S38	3.604E+14	3.280E+15	0.9887579	2.061E-02	3.644E-02	0.565
S66	1.302E+16	1.866E+16	0.9995162	5.704E-04	6.716E-04	0.849
S67	9.067E+15	1.963E+16	0.9994019	8.190E-04	1.120E-03	0.731
S71	2.166E+15	2.561E+16	0.9981463	3.428E-03	6.301E-03	0.544
S83	1.263E+16	6.036E+16	0.9996446	5.881E-04	9.722E-04	0.605
S87	9.511E+15	2.346E+16	0.9994518	7.808E-04	1.110E-03	0.703
S96	1.757E+16	2.287E+16	0.9996265	4.226E-04	4.778E-04	0.885
S97	1.997E+16	3.725E+16	0.9997145	3.719E-04	4.840E-04	0.768
S2	1.673E+14	3.114E+15	0.9774097	4.438E-02	8.077E-02	0.549
S102	4.184E+14	2.197E+15	0.9896012	1.775E-02	2.936E-02	0.604

Table 12: Classical theory for $M_C = 1 \times 10^{40}$ kg, $r_g = 7.43 \times 10^{12}$ m, density = 5.83 kg/m^3.

star	r_p (m)	r_a (m)	ω_a/π	ρ_0	β_0^2	σ_0
S1	3.347E+15	9.936E+15	1	2.218E-03	3.319E-03	0.668
S2	1.936E+14	3.033E+15	1	3.836E-02	7.212E-02	0.532
S4	2.319E+15	5.490E+15	1	3.202E-03	4.502E-03	0.711
S5	5.174E+14	6.032E+15	1	1.435E-02	2.644E-02	0.543
S6	6.500E+14	1.075E+16	1	1.142E-02	2.155E-02	0.530
S8	9.460E+14	9.804E+15	1	7.850E-03	1.432E-02	0.548
S9	6.717E+14	7.005E+15	1	1.105E-02	2.017E-02	0.548
S12	4.035E+14	7.666E+15	1	1.841E-02	3.497E-02	0.526
S13	1.985E+15	5.798E+15	1	3.742E-03	5.575E-03	0.671
S14	1.240E+14	6.577E+15	1	5.990E-02	1.176E-01	0.509
S17	2.585E+15	5.544E+15	1	2.873E-03	3.918E-03	0.733
S18	8.379E+14	6.116E+15	1	8.862E-03	1.559E-02	0.569
S19	1.628E+15	1.924E+16	1	4.561E-03	8.411E-03	0.542
S21	6.011E+14	4.964E+15	1	1.235E-02	2.204E-02	0.561
S24	9.287E+14	2.679E+16	1	7.996E-03	1.546E-02	0.517
S27	2.857E+14	1.162E+16	1	2.599E-02	5.073E-02	0.512
S29	4.354E+14	9.930E+15	1	1.706E-02	3.268E-02	0.522
S31	2.574E+14	7.543E+15	1	2.885E-02	5.579E-02	0.517
S33	1.445E+15	9.297E+15	1	5.140E-03	8.897E-03	0.578
S38	3.599E+14	3.275E+15	1	2.063E-02	3.718E-02	0.555
S66	1.302E+16	1.865E+16	1	5.705E-04	6.720E-04	0.849
S67	9.066E+15	1.962E+16	1	8.191E-04	1.121E-03	0.731
S71	2.166E+15	2.560E+16	1	3.428E-03	6.322E-03	0.542
S83	1.263E+16	6.036E+16	1	5.882E-04	9.728E-04	0.605
S87	9.509E+15	2.345E+16	1	7.809E-04	1.111E-03	0.703
S96	1.757E+16	2.286E+16	1	4.227E-04	4.781E-04	0.884
S97	1.997E+16	3.725E+16	1	3.719E-04	4.842E-04	0.768
S2	1.671E+14	3.109E+15	1	4.444E-02	8.435E-02	0.527
S102	4.177E+14	2.193E+15	1	1.778E-02	2.987E-02	0.595

Table 13: GR theory for $M_C = 1 \times 10^{40}$ kg, $r_g = 7.43 \times 10^{12}$ m, density = 5.83 kg/m^3.

star	r_p (m)	r_a (m)	ω_a/π	ρ_0	β_0^2	σ_0
S1	3.343E+15	9.924E+15	1.0044842	2.221E-03	3.339E-03	0.665
S2	1.926E+14	3.017E+15	1.0682010	3.856E-02	7.857E-02	0.491
S4	2.315E+15	5.479E+15	1.0069168	3.208E-03	4.543E-03	0.706
S5	5.162E+14	6.018E+15	1.0243242	1.439E-02	2.729E-02	0.527
S6	6.491E+14	1.074E+16	1.0187328	1.144E-02	2.208E-02	0.518
S8	9.446E+14	9.790E+15	1.0131957	7.861E-03	1.457E-02	0.540
S9	6.704E+14	6.991E+15	1.0187416	1.108E-02	2.068E-02	0.536
S12	4.027E+14	7.651E+15	1.0305203	1.844E-02	3.638E-02	0.507
S13	1.981E+15	5.787E+15	1.0076362	3.749E-03	5.632E-03	0.666
S14	1.237E+14	6.560E+15	1.1077995	6.005E-02	1.340E-01	0.448
S17	2.580E+15	5.534E+15	1.0063907	2.878E-03	3.951E-03	0.728
S18	8.361E+14	6.103E+15	1.0155125	8.881E-03	1.591E-02	0.558
S19	1.627E+15	1.923E+16	1.0075133	4.565E-03	8.495E-03	0.537
S21	5.994E+14	4.951E+15	1.0215321	1.239E-02	2.267E-02	0.546
S24	9.282E+14	2.678E+16	1.0126644	8.000E-03	1.572E-02	0.509
S27	2.853E+14	1.160E+16	1.0427174	2.602E-02	5.359E-02	0.486
S29	4.347E+14	9.916E+15	1.0279270	1.708E-02	3.389E-02	0.504
S31	2.569E+14	7.527E+15	1.0482872	2.891E-02	5.934E-02	0.487
S33	1.443E+15	9.284E+15	1.0090449	5.147E-03	9.004E-03	0.572
S38	3.584E+14	3.261E+15	1.0364695	2.072E-02	3.897E-02	0.532
S66	1.301E+16	1.865E+16	1.0014567	5.707E-04	6.733E-04	0.848
S67	9.061E+15	1.961E+16	1.0018021	8.195E-04	1.123E-03	0.730
S71	2.165E+15	2.559E+16	1.0056297	3.430E-03	6.369E-03	0.539
S83	1.262E+16	6.034E+16	1.0010688	5.883E-04	9.742E-04	0.604
S87	9.505E+15	2.344E+16	1.0016512	7.812E-04	1.114E-03	0.702
S96	1.756E+16	2.286E+16	1.0011235	4.229E-04	4.788E-04	0.883
S97	1.996E+16	3.724E+16	1.0008582	3.720E-04	4.848E-04	0.767
S2	1.662E+14	3.093E+15	1.0795747	4.467E-02	9.312E-02	0.480
S102	4.152E+14	2.180E+15	1.0336032	1.789E-02	3.120E-02	0.573

FINAL NOTE

The Milky Way observations are very well consistent with the GU Model predictions of the existence of matter-antimatter TUs and their evolution. The scenario of Milky Way state of destruction during the two TUs collision explains many puzzles and mysteries appeared from the observations.

The existing treatment of MW observations are based on Newtonian Physics with constraints imposed by GR Dynamics, which requires the existence of the Schwarzschild horizon. Those parameters are obtained from extremely complex computer programs reconstructing physical pictures of orbits from observational databases subjected to significant uncertainties caused, firstly, to poor resolutions, secondly, lack of observational time. Therefore, the results of calculations can be to some extent influenced by the GR methodology and the conventional concepts of galaxies. The influence is possible, at least, for some orbits, which could approach the center closer than it is assessed.

In our calculations, we used those parameters with no surprise that our results agrees with published in literature. It would be interesting to recalculate the results with the parameters of orbits originally assessed from the unfolding programs with the replacement of the GR methodology by the Alternative one from the GU Cosmological Model. This would be the only way allowing to reveal possible evidences of relativistic effects contradicting to the GR predictions.